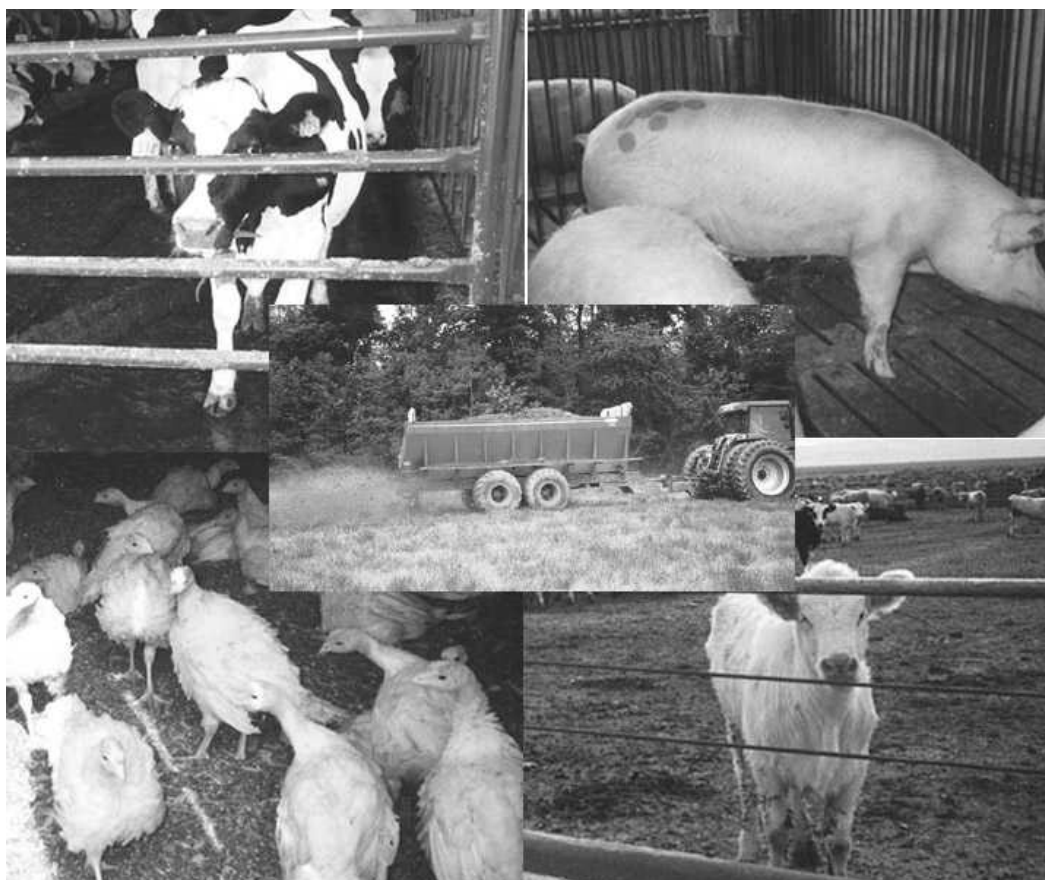




# **Environmental and Economic Benefit Analysis of Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations**

December 2002



U.S. Environmental Protection Agency  
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**ENVIRONMENTAL AND ECONOMIC BENEFIT ANALYSIS OF  
FINAL REVISIONS TO THE NATIONAL POLLUTANT  
DISCHARGE ELIMINATION SYSTEM REGULATION AND  
THE EFFLUENT GUIDELINES FOR  
CONCENTRATED ANIMAL FEEDING OPERATIONS**

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## EXECUTIVE SUMMARY

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This report presents EPA's estimates of the environmental and human health benefits, including pollutant reductions, that will occur from the Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations (final rule).

A number of the practices used to manage animal wastes at concentrated animal feeding operations (CAFOs) can have adverse impacts on the environment. For example, waste lagoons that are not properly managed can leak or overflow; land application of manure can exceed the ability of the land to absorb nutrients; and management of large quantities of litter in uncovered outdoor stacks can allow excessive runoff during rain events. All of these practices can result in releases of manure to surface waters, where nutrients, solids, and pathogens in the waste cause damage to aquatic life (including large fish kills) and risks to human health from drinking or swimming in contaminated water. Releases can also cause degradation of groundwater and air-related impacts. The severity of potential environmental and health impacts can be exacerbated when operations are very large or are concentrated geographically. Recent industry trends have resulted both in larger operations (i.e., with more animals) and in greater regional concentration of facilities.

Several recent events, including large manure releases in North Carolina and incidences of drinking water contamination related to livestock, have highlighted the need to update regulations to improve management of animal wastes. Moreover, emerging research on the health effects of various compounds (e.g., hormones) found in manure suggests that the impact of manure on human and animal populations may be broader than previously understood.

USDA estimates that in 1997 manure generation from all livestock and poultry production totaled 1.1 billion tons — six times the waste generated by humans in the United States. Confined animals account for roughly half (500 million tons) of the animal waste produced. While strict pollutant discharge limits have been applied to human waste treatment facilities for years, regulation for animal waste, even of large CAFOs that generate as much waste as a small town, has typically been less stringent.



EPA's final rule expands the scope and extends the requirements of the current regulations addressing CAFOs. EPA has developed this rule to respond to pollution problems associated with animal waste management that have occurred even in the presence of existing regulations. Specifically, manure land application requirements under existing effluent guidelines do not ensure that manure is applied at rates that prevent excessive nutrients from migrating into surface waters. In addition, the current regulations do not address a number of facility types (e.g., dry poultry operations) that have emerged or become more prevalent due to changes in the industry since 1976. The final rule specifies more stringent animal waste management practices than are currently required at regulated facilities, and also extends these requirements to a number of facilities that are not currently regulated.

## SUMMARY OF BENEFITS

EPA's economic analysis of the benefits of the revised CAFO standards focuses solely on the benefits attributable to changes in regulations governing Large CAFOs. Exhibit ES-1 summarizes these benefits on an annualized basis. The total benefits associated with requirements for Large CAFOs exceed the range of \$204 + [B] million to \$355 + [B] million. The values presented in the range represent those benefits for which EPA is able to quantify and determine an economic value. The factor "B" refers to the benefits identified by EPA that cannot be quantified at this time. EPA has identified substantial additional environmental benefits that will result from the rule, but is unable to attribute a specific economic value to these additional benefits.

<b>Exhibit ES-1</b>  <b>ANNUALIZED BENEFITS OF THE REVISED REGULATORY STANDARDS FOR LARGE CAFOS*</b> <b>(millions of 2001\$)</b>		
<b>Types of Benefits</b>	<b>3 Percent Discount Rate</b>	<b>7 Percent Discount Rate</b>
Recreational and non-use benefits from improved water quality in rivers and streams	\$166.2 - \$298.6	\$166.2 - \$298.6
Reduced fish kills	\$0.1	\$0.1
Improved shellfish harvests	\$0.3 - \$3.4	\$0.3 - \$3.4
Reduced nitrate contamination of private wells	\$45.7	\$30.9
Reduced contamination of animal water supplies	\$5.3	\$5.3

<b>Exhibit ES-1</b>  <b>ANNUALIZED BENEFITS OF THE REVISED REGULATORY STANDARDS FOR LARGE CAFOS*</b> <b>(millions of 2001\$)</b>		
<b>Types of Benefits</b>	<b>3 Percent Discount Rate</b>	<b>7 Percent Discount Rate</b>
Reduced eutrophication of estuaries and coastal waters	not monetized	not monetized
Case study of potential recreational fishing benefits to the Albemarle-Pamlico Estuary	\$0.2	\$0.2
Reduced public water treatment costs	\$1.1 - \$1.7	\$1.1 - \$1.7
Reduced pathogen contamination of private & public underground sources of drinking water	not monetized	not monetized
Reduced human & ecological risks from antibiotics, hormones, metals, salts	not monetized	not monetized
Improved soil properties	not monetized	not monetized
Other benefits	not monetized	not monetized
Total Benefits	\$218.9 + [B] to \$355.0 + [B]**	\$204.1 + [B] to \$340.2 + [B]**
* Benefit estimates do not include reduced impacts from medium-sized CAFOs. ** [B] represents non-monetized benefits of the rule.		

## KEY FEATURES OF THE FINAL RULE

EPA is revising both the National Pollutant Discharge Elimination System (NPDES) regulations for CAFOs and the Effluent Limitation Guidelines (ELGs) for feedlots. The revised NPDES regulations for CAFOs affect which animal feeding operations (AFOs) are defined as CAFOs and are therefore subject to the NPDES permit program. Changes to the ELGs for feedlots affect which technology-based requirements will apply to certain CAFOs.

### Operations Regulated under Final Rule

USDA reports that there were 1.2 million livestock and poultry operations in the United States in 1997. This number includes all operations that raise beef or dairy cattle, hogs, chickens (broilers or layers), and turkeys, and includes both confinement and non-confinement (i.e., grazing and ranged) production. Of these, EPA estimates that there are about 238,000 AFOs that raise or house animals in confinement. EPA has further estimated that 15,198 facilities will be CAFOs subject to the final rule, based on the number of facilities that discharge or have the potential to

discharge to U.S. waters and which meet the minimum size thresholds (i.e., number of animals) defined by the revised regulations (Exhibit ES-2).

<b>Exhibit ES-2</b>				
<b>ESTIMATED NUMBER OF CAFOS SUBJECT TO REVISED REGULATIONS*</b>				
<b>Production Sector</b>	<b>Currently Regulated</b>	<b>Regulated Under New Rule</b>		
		<b>Large CAFOs</b>	<b>Medium CAFOs</b>	<b>Total</b>
Beef	1,940	1,766	174	1,940
Dairy	3,399	1,450	1,949	3,399
Heifers	0	242	230	472
Veal	0	12	7	19
Swine	5,409	3,924	1,485	5,409
Layers	433	1,112	50	1,162
Broilers	683	1,632	520	2,152
Turkeys	425	388	37	425
Horses	195	195	0	195
Ducks	21	21	4	25
<b>Total</b>	<b>12,505</b>	<b>10,742</b>	<b>4,456</b>	<b>15,198</b>
* AFOs that stable or confine animals in different sectors are counted more than once.				

### **Definition of CAFO under the Final Rule**

EPA's final rule defines CAFOs in three categories: Large, Medium, and Small (see Exhibit ES-3 for the size standards). The revised regulations require all large CAFOs to apply for an NPDES permit. This includes several types of operations that were previously not considered CAFOs, including: large facilities that discharge only as the result of a large storm event; large "dry" poultry operations; and stand-alone immature swine or heifer operations. In the rare event that a large CAFO has no potential to discharge, the new requirements provide a process for a demonstration to that effect, in lieu of obtaining a permit.

Medium-size AFOs are defined as CAFOs only if they meet one of two specific criteria governing the method of discharge:

- Pollutants are discharged into waters of the United States through a manmade ditch, flushing system, or other similar man-made device; or
- Pollutants are discharged directly into waters of the United States that originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the confined animals.

<b>Exhibit ES-3</b>			
<b>SIZE STANDARDS FOR LARGE, MEDIUM, AND SMALL CAFOS</b>			
<b>Sector</b>	<b>Large</b>	<b>Medium<sup>1</sup></b>	<b>Small<sup>2</sup></b>
Mature Dairy Cattle	more than 700	200 - 700	less than 200
Veal Calves	more than 1,000	300 - 1,000	less than 300
Cattle or Cow/Calf Pairs	more than 1,000	300 - 1,000	less than 300
Swine (weighing over 55 pounds)	more than 2,500	750 - 2,500	less than 750
Swine (weighing less than 55 pounds)	more than 10,000	3,000 - 10,000	less than 3,000
Horses	more than 500	150 - 500	less than 150
Sheep or Lambs	more than 10,000	3,000 - 10,000	less than 3,000
Turkeys	more than 55,000	16,500 - 55,000	less than 16,500
Chickens (liquid manure handling systems)- includes Laying Hens	more than 30,000	9,000 - 30,000	less than 9,000
Chickens Other than Laying Hens (other than liquid manure handling)	more than 125,000	37,500 - 125,000	less than 37,500
Laying Hens (other than liquid manure handling)	more than 82,000	25,000 - 82,000	less than 25,000
Ducks (dry operations)	more than 30,000	10,000 - 30,000	less than 10,000
Ducks (wet operations)	more than 5,000	1,500 - 5,000	less than 1,500
<sup>1</sup> Must also meet one of two criteria to be defined as a CAFO.			
<sup>2</sup> Must be designated by EPA or the State permit authority.			

Similarly, small facilities are considered CAFOs only if they are designated as such by EPA or the State NPDES permit authority. Such designation must be based on a determination that a

facility is a significant contributor of pollutants to waters of the United States. On identical grounds, medium-size operations that are not CAFOs by definition may also be designated as CAFOs.

Under the final rule all CAFOs, regardless of size, must apply for an NPDES permit and must develop and implement a nutrient management plan. Such plans must identify practices necessary to demonstrate compliance with the effluent limitation guideline (if applicable), and include requirements to land apply manure and wastewater in a manner consistent with technical standards for nutrient management established to ensure appropriate utilization of nutrients.

### **Effluent Limitation Guidelines under the Final Rule**

EPA's final rule also applies revised effluent guidelines to large CAFOs; for other permitted facilities, technology-based discharge limits will be established on the basis of the permit writer's best professional judgment. The key feature of these requirements is prohibition of discharge of manure and other process wastewater from the production area.<sup>1</sup> An exception to this restriction is made for rainfall-related overflows from facilities that are designed, constructed, operated, and maintained to contain all process wastewater and runoff from a 25-year, 24-hour (or more severe) rainfall event. In addition, the ELG requires all large CAFOs to comply with best management practices to ensure the proper application of manure, including a requirement to apply manure at rates based on technical standards for nutrient management.<sup>2</sup>

### **ENVIRONMENTAL IMPACTS ADDRESSED UNDER THE FINAL RULE**

The release of pollutants in animal waste from CAFOs to surface water, groundwater, soil, and air is associated with a range of human health and ecological impacts, and contributes to the degradation of the nation's surface water. Data collected for EPA's 2000 *National Water Quality Inventory*, prepared under Section 305(b) of the Clean Water Act, identify agriculture (including irrigated and non-irrigated crop production, rangeland, feedlots, pastureland, and animal holding areas) as the leading contributor to identified water quality impairments in the nation's rivers and lakes, and the fifth leading contributor to identified water quality impairments in the nation's estuaries. The data indicate that the agricultural sector contributes to the impairment of at least 129,000 river miles, 3.2 million lake acres, and over 2,800 square miles of estuary. Animal feeding operations are only a subset of the agriculture category, but 29 states specifically identified animal feeding operations as contributing to water quality impairment. Finally, the data also identify the

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<sup>1</sup> The production area of an AFO includes the animal confinement area, the litter or manure storage area, the raw materials storage area, and the waste containment area.

<sup>2</sup> These requirements apply to any land under the control of the owner or operator of the production area — whether it is owned, rented, or leased — to which manure and wastewater from the production area is applied.

key pollutants and stressors that impair the nation's waters. Among the most problematic pollutants are several - including pathogens, nutrients, and oxygen depleting substances - that are associated commonly, although not exclusively, with animal waste.

### **Key Pollutants in Animal Waste**

The primary pollutants associated with animal wastes are nutrients (particularly nitrogen and phosphorus), organic matter, solids, pathogens, and odorous/volatile compounds. Animal waste is also a source of salts and trace elements, and to a lesser extent, antibiotics, pesticides, and hormones. Exhibit ES-4 describes the key pollutants in animal waste, the pathways by which they reach the environment, and their potential impacts.

<b>Exhibit ES-4</b>			
<b>KEY POLLUTANTS IN ANIMAL WASTE</b>			
<b>Pollutant</b>	<b>Description of Pollutant Forms in Animal Waste</b>	<b>Pathways</b>	<b>Potential Impacts</b>
<b>Nutrients</b>			
Nitrogen	Exists in fresh manure in organic (e.g., urea) and inorganic forms (e.g., ammonium and nitrate). Microbes transform organic nitrogen to inorganic forms that may be absorbed by plants.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Leachate into groundwater</li> <li>▶ Atmospheric deposition as ammonia</li> </ul>	<ul style="list-style-type: none"> <li>▶ Eutrophication</li> <li>▶ Animal, human health effects</li> </ul>
Phosphorus	Exists in both organic and inorganic forms. As manure ages, phosphorus mineralizes to inorganic phosphate compounds that may be absorbed by plants.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Leachate into groundwater (water soluble forms)</li> </ul>	<ul style="list-style-type: none"> <li>▶ Eutrophication</li> </ul>
Potassium	Most potassium in manure is in an inorganic form available for absorption by plants; it can also be stored in soil for future uptake.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Leachate into groundwater</li> </ul>	<ul style="list-style-type: none"> <li>▶ Increased salinity</li> </ul>
<b>Organic Compounds</b>	Carbon-based compounds in manure that are decomposed by soil and surface water micro-organisms. Creates biochemical oxygen demand, or BOD, because decomposition consumes dissolved oxygen in the water.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> </ul>	<ul style="list-style-type: none"> <li>▶ Depletion of dissolved oxygen</li> <li>▶ Reduction in aquatic life</li> <li>▶ Eutrophication</li> </ul>
<b>Solids</b>	Includes manure itself and other elements (e.g., feed, bedding, hair, feathers, and corpses).	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Atmospheric deposition</li> </ul>	<ul style="list-style-type: none"> <li>▶ Turbidity</li> <li>▶ Siltation</li> </ul>
<b>Pathogens</b>	Includes range of disease-causing organisms, including bacteria, viruses, protozoa, fungi, and algae. Some pathogens are found in manure, others grow in surface water due to increased nutrients and organic matter.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Growth in waters with high nutrient, organic materials</li> </ul>	<ul style="list-style-type: none"> <li>▶ Animal, human health effects</li> </ul>

Exhibit ES-4			
KEY POLLUTANTS IN ANIMAL WASTE			
Pollutant	Description of Pollutant Forms in Animal Waste	Pathways	Potential Impacts
<b>Salts</b>	Includes cations sodium, potassium, calcium, and magnesium; and anions chloride, sulfate, bicarbonate, carbonate, and nitrate.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Leachate into groundwater</li> </ul>	<ul style="list-style-type: none"> <li>▶ Reduction in aquatic life</li> <li>▶ Human health effects</li> <li>▶ Soil impacts</li> </ul>
<b>Trace Elements</b>	Includes feed additives arsenic, copper, selenium, zinc, cadmium; and trace metals molybdenum, nickel, lead, iron, manganese, aluminum, and boron (pesticide ingredients).	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> </ul>	<ul style="list-style-type: none"> <li>▶ Toxicity at high levels</li> </ul>
<b>Volatile Compounds</b>	Includes carbon dioxide, methane, nitrous oxide, hydrogen sulfide, and ammonia gases generated during decomposition of waste.	<ul style="list-style-type: none"> <li>▶ Inhalation</li> <li>▶ Atmospheric deposition of ammonia</li> </ul>	<ul style="list-style-type: none"> <li>▶ Human health effects</li> <li>▶ Eutrophication</li> <li>▶ Global warming</li> </ul>
<b>Other Pollutants</b>	Includes pesticides, antibiotics, and hormones used in feeding operations.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> </ul>	<ul style="list-style-type: none"> <li>▶ <i>Impacts unknown</i></li> </ul>

### **Pollutant Pathways**

Pollutants in animal waste and manure enter the environment through a number of pathways, including surface runoff and erosion, direct discharges to surface water, spills and other dry-weather discharges, leaching into soil and ground water, and releases to air (including subsequent redeposition to land and surface waters). Releases of manure pollutants can originate from animal confinement areas, manure handling and containment systems, manure stockpiles, and from cropland where manure is spread.

Runoff and erosion occur during rainfall, when rain water carries pollutants over land to surface waters. Runoff of animal wastes is more likely when rainfall occurs soon after application and when manure is over-applied or misapplied. Erosion can be a significant transport mechanism for land applied pollutants, such as phosphorus, that are strongly bonded to soils.

Direct discharge of pollutants to surface water occurs when animals have access to water bodies and when manure storage areas overflow. Dry weather discharges to surface waters result from accidental (or intentional) discharges from lagoons and irrigation systems. Other discharges to surface waters include overflows from containment systems following rainfall, catastrophic spills from failure of manure containment systems, washouts from floodwaters, or equipment malfunction, such as pump or irrigation gun failure.

Discharge to groundwater occurs when water traveling through the soil to ground water carries with it pollutants (e.g., nitrates) from livestock and poultry wastes on the surface. Leaking lagoons are also a potential source of manure pollutants in ground water.

Air releases of CAFO pollutants result from volatilization of manure constituents and the products of manure decomposition. Alternatively, manure pollutants can enter the air through spray irrigation systems and as particulates wind-borne in dust. Once airborne, these pollutants can settle in nearby water bodies, or can be directly inhaled.

### **Impacts of Pollutants in Animal Waste**

The most dramatic ecological impacts associated with manure pollutants in surface waters are massive fish kills. Incomplete records indicate that every year dozens of fish kills associated with AFOs result in the deaths of hundreds of thousands of fish. In addition, manure pollutants such as nutrients and suspended solids can seriously disrupt aquatic systems by over-enriching water (in the case of nutrients) or by increasing turbidity (in the case of solids). Excess nutrients cause fast-growing algae blooms that reduce the penetration of sunlight in the water column, and reduce the amount of available oxygen in the water, reducing fish and shellfish habitat and affecting fish and invertebrates. Manure pollutants can also encourage the growth of toxic organisms, including *Pfiesteria*, which has also been associated with fish kills and fish disease events. Reduction in biodiversity due to animal feeding operations has also been documented; for example, a study of three Indiana stream systems found fewer fish and more limited diversity of fish species downstream of CAFOs than were found downstream of study reference sites.

A variety of pollutants in animal waste can also affect human health. Manure contains over 100 human pathogens; contact with some of these pathogens during recreational activities in surface water can result in infections of the skin, eye, ear, nose, and throat. Eutrophication due to excess nutrients can also promote blooms of a variety of organisms that are toxic to humans either through ingestion or contact. This includes the dinoflagellate *Pfiesteria piscicida*. While *Pfiesteria* is primarily associated with fish kills and fish disease events, the organism has also been linked with human health impacts through dermal exposure. Finally, even with no visible signs of algae blooms, shellfish such as oysters, clams and mussels can carry toxins produced by some types of algae in their tissue. These can affect people who eat contaminated shellfish.

Contaminants from manure, including nitrogen, algae, and pathogens, can also affect human health through drinking water sources and can result in increased drinking water treatment costs. For example, nitrogen in manure can be transported to drinking water as nitrates, which are associated with human health risks. EPA has identified nitrate as the most widespread agricultural contaminant in drinking water wells. Algae blooms triggered by nutrient pollution can affect drinking water by clogging treatment plant intakes, producing objectionable tastes and odors, and reacting with the chlorine used to disinfect drinking water to produce harmful chlorinated byproducts (e.g., trihalomethanes).



## REDUCTIONS IN POLLUTANT DISCHARGES UNDER THE FINAL RULE

EPA's analysis of pollutant discharges under the final rule addresses changes in pollutant discharges occurring at the production area, and also changes in the quantity of pollutants in runoff from land on which manure has been applied. Estimates of pollutant discharges from these manure application sites, or "edge-of-field" loadings, include nutrients, metals, pathogens, and sediment for both pre-rule conditions (baseline) and post-rule conditions. EPA estimated reductions in pollutant discharges using the Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model, which uses information on soil characteristics and climate, along with characteristics of the applied manure and commercial fertilizers, to estimate losses of nutrients, metals, pathogens, and sediment in surface runoff, sediment, and ground water leachate.

EPA used GLEAMS to quantify the reduction of nitrogen and phosphorus loads, and reductions of discharges of zinc, copper, cadmium, nickel, lead, and arsenic. Fecal coliform and Fecal streptococcus were used as surrogates to estimate pathogen reductions that would likely be achieved by this rule. Table ES-5 presents the results of these analyses.

<b>Exhibit ES-5</b>				
<b>EDGE OF FIELD LOADING REDUCTIONS FOR LARGE CAFOS: COMBINED TOTAL FOR ALL ANIMAL SECTORS</b>				
<b>Parameter/Units</b>	<b>Baseline Pollutant Loading (Pre-regulation)</b>	<b>Post-regulation Pollutant Loading</b>	<b>Pollutant Reduction</b>	
			<b>Units</b>	<b>Percent</b>
Nutrients (million lb.)	658	503	155	24
Metals (million lb.)	20	19	1	5
Pathogens (10 <sup>19</sup> cfu)	5,784	3,129	2,655	46
Sediment (million lb.)	35,493	33,434	2,059	6

## APPROACHES TO ANALYZING BENEFITS OF THE FINAL RULE

EPA has analyzed the water quality improvements attributable to the regulation of large CAFOs under the final rule and has estimated the environmental and human health benefits of the pollutant reductions that will result. The monetized benefits generally reflect direct improvements in surface and groundwater quality, but the rule will also result in benefits associated with improved soil conditions, costs associated with increased energy consumption, and changes in emissions of air pollutants.

EPA's benefits analysis estimates the effect of pollutant reductions and other environmental improvements on human health and the ecosystem, and to the extent possible assigns a monetary value to these benefits. As previously noted, the analysis focuses solely on the benefits attributable to the revised standards for large CAFOs; the impacts of the final rule on medium-sized CAFOs are not considered. In addition, EPA has identified certain types of environmental improvements that will result from this rule that it is unable to quantify or value. Given the limitations in assigning monetary values to some of the improvements, the economic benefit values summarized in Exhibit ES-1 and described in the Benefits Analysis should be considered a subset of the total benefits of the new regulations. These monetized benefits should be evaluated along with descriptive qualitative assessments of the non-monetized benefits with the acknowledgment that even these may fall short of the real-world benefits that may result from this rule. For example, the benefits analysis assigns monetary values to water quality improvements due to reductions of nitrogen, phosphorus, pathogens and sediment, but does not include values for potential water quality improvements expected due to reduced discharges of metals or hormones.

To estimate the impacts of controlling animal waste from CAFOs, EPA conducted seven benefit studies. The first analysis employs a national water quality model (National Water Pollution Control Assessment Model) that estimates runoff from land application areas to rivers, streams, and, to a lesser extent, lakes in the U.S. This study estimates the value society places on improvements in surface water quality associated with the revised rule. The second analysis examines the expected improvements in shellfish harvesting resulting from improved water quality under the new CAFO rule. A third study looks at the fish kills that are attributed to animal feeding operations and estimates the benefits of reducing such incidents. The fourth analysis estimates the benefits associated with reduced contamination of groundwater for people who draw their water from private wells, while the fifth examines the benefits of reduced contamination of animal water supplies. The sixth analysis presents a case study of the benefits of reducing the discharge of nutrients to estuaries, focusing on North Carolina's Albemarle and Pamlico Sounds. Finally, the seventh study evaluates the beneficial impact of improved source water quality on the cost of treating public water supplies.

Research documented in the record and summarized in the Benefits Analysis shows that CAFO wastes affect the environment and human health in a number ways beyond those for which benefits have been monetized. Examples of other types of impacts or potential benefits include:

- **Reductions in loadings of metals, antibiotics, hormones, salts, and other pollutants** in animal waste from CAFOs, and reductions in associated human health and ecological effects;
- **Reduced eutrophication** of coastal and estuarine waters beyond the Albemarle and Pamlico Sounds region, due to reductions in nutrient-rich runoff from CAFOs and reductions in the deposition of  $\text{NH}_3$  (ammonia) volatilized from CAFOs;

- **Reduced human exposure to pathogens** during recreational activities in estuaries and coastal waters;
- **Potential improvements to soil properties** due to reduced overapplication of manure and an increase in the acreage of land to which manure is applied at agronomic rates; and
- **Reduced pathogen contamination** in private drinking water wells.

EPA's benefits analysis does not include monetary values for these other areas of environmental improvements. In some cases, data limitations prevent the measurement of the magnitude of improvement. In other cases, the economic literature does not support the development of an economic value for these benefits. Nevertheless, these environmental benefits are tangible and result in improved ecological conditions and reduced risk to human health.

The U.S. Environmental Protection Agency (EPA) is revising and updating the two primary regulations that ensure that manure, litter, wastewater, and other process waters generated by concentrated animal feeding operations (CAFOs) do not impair water quality.<sup>1</sup> EPA's regulatory changes affect the existing National Pollutant Discharge Elimination System (NPDES) provisions that define and establish permit requirements for CAFOs, and the existing effluent limitations guidelines (ELGs) for feedlots, which establish the technology-based effluent discharge standard that is applied to specified CAFOs. Both of these existing regulations were originally promulgated in the 1970s. EPA is revising the regulations to address changes that have occurred in the animal industry sectors over the last 25 years, to clarify and improve implementation of CAFO requirements, and to improve the environmental protection achieved under these rules.

This report addresses the environmental and economic benefits of the revised regulations. It examines in detail several environmental quality improvements that EPA expects will result from the regulatory changes: improvements in the suitability of freshwater resources for recreational activities; reduced incidence of fish kills; improved commercial shellfishing; reduced contamination of private wells; reduced contamination of animal water supplies; reduced eutrophication of estuaries; and improvements in source water quality that will reduce drinking water treatment costs for public water supply systems. Because these are not the only beneficial impacts of the revised regulations — and because, in general, EPA takes a conservative approach to quantifying the benefits analyzed — the Agency believes that this report presents a lower-bound estimate of the beneficial impacts of the new CAFO rules.

This chapter first provides background information on animal feeding operations and EPA's previously established CAFO regulations. It then briefly summarizes the environmental problems and industry changes associated with animal feeding operations that EPA is addressing with its revised regulations. Finally, the chapter outlines the regulatory changes that EPA is implementing, and provides a summary of the methods and results of the detailed benefits analyses presented in

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<sup>1</sup> As used throughout this report, the term manure is defined to include manure, litter, and other process wastewater generated by CAFOs.

subsequent chapters of the report. The detailed analyses and summary present the economic benefits of the standards promulgated by the Agency for the NPDES provisions and ELGs.

It is important to note that the analysis that EPA has conducted focuses solely on the economic benefits attributable to the revised standards for large CAFOs; the potential beneficial impact of the revised standards for medium-sized CAFOs is not addressed. The analysis assumes that affected CAFOs will land-apply manure, litter, and other process wastewater in accordance with a nutrient management plan that establishes application rates for each field based on the nitrogen requirements of the crop, or on the crop's phosphorus requirements where necessary because of soil or other field conditions. The promulgated regulation requires CAFOs to prepare and implement a site-specific nutrient management plan that establishes manure application rates for each field based on the technical standards for nutrient management established by the permitting authority's director. The promulgated standard is referred to throughout this report as the phosphorus-based standard. The report also presents results for a nitrogen-based regulatory alternative that the Agency considered but did not select.

## **1.1 BACKGROUND INFORMATION**

### **1.1.1 Definition and Population of AFOs**

The term CAFO is a regulatory designation that describes certain animal feeding operations (AFOs). AFOs are defined by federal regulation as lots or facilities where animals "have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility" (40 CFR 122.23(b)(1)). AFOs congregate animals on a small land area where feed must be brought to the animals. Winter feeding of animals on pasture or rangeland is not normally considered an AFO.

USDA reports that there were 1.2 million livestock and poultry operations in the United States in 1997. This number includes all operations that raise beef or dairy cattle, hogs, chickens (broilers or layers), and turkeys, and includes both confinement and non-confinement (i.e., grazing and ranged) production. Of these, EPA estimates that there are about 238,000 AFOs that raise or house animals in confinement, as defined by the USDA. For many of the animal sectors, it is not possible to estimate from available data what proportion of the total livestock operations have feedlots (i.e., confinement) and what proportion are grazing operations only. For analytical purposes, EPA has therefore assumed that all dairy, hog, and poultry operations are AFOs. Exhibit 1-1 summarizes the estimated total number of AFOs of all sizes in each of the four major livestock categories, based on 1997 data.

<b>Exhibit 1-1</b>  <b>NUMBER OF ANIMAL FEEDING OPERATIONS</b> <b>(based on 1997 data)</b>	
<b>Sector</b>	<b>Total AFOs</b>
Beef operations, including both cattle and veal operations.	57,598
Dairy operations, including both milk and heifer operations.	98,630
Hog operations, including both "farrow to finish" and "grower to finish" operations.	51,772
Poultry operations, including broilers, layers (both wet and dry operations) and turkeys.	27,530
<b>Sum Total</b>	<b>235,530</b>
<b>Total AFOs<sup>1</sup></b>	<b>237,821</b>
Source: EPA estimates derived from published USDA/NRCS data. For more information, see Robert L. Kellogg, <i>Profile of Farms with Livestock in the United States: A Statistical Summary</i> , USDA/NRCS, 2002. <sup>1</sup> "Total AFOs" accounts for "specialty cases" defined as dairies that went out of business, farms with only feeder pigs, and egg hatching operations.	

### 1.1.2 Existing Regulations for CAFOs

The regulations that EPA established in the 1970s identify three categories of AFOs that are subject to regulation as CAFOs. The first category of facilities includes any animal feeding operation where more than 1,000 "animal units" (AUs) are confined; such facilities are by definition CAFOs unless discharges from the operation occurred only as the result of a 25-year, 24-hour (or more severe) storm event.<sup>2</sup> The second group of facilities includes AFOs that confine 300 to 1000 AUs; these facilities are defined as CAFOs if:

- Pollutants were discharged into navigable waters through a manmade ditch, flushing system, or other similar man-made device; or
- Pollutants were discharged directly into waters that originate outside of and pass over, across, or through the facility or come into direct contact with the confined animals.

The established regulations do not extend the definition of a CAFO to operations with fewer than 300 AUs. Under certain circumstances, however (e.g., a facility causing significant surface water impairment), a permitting authority may designate such facilities as CAFOs.

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<sup>2</sup> Animal units are defined in EPA's current regulations at 40 CFR 122 and vary by animal type. An AU is considered equivalent to one beef cow.

On the basis of the manure management or watering systems they employ, the established regulations do not define certain poultry operations as CAFOs. In addition, the CAFO definition considers only swine over 55 pounds and mature dairy cattle, assuming that immature swine and heifers would be raised in the same operations as adults. As a result, the regulatory definition does not address the "stand-alone" immature swine or heifer operations that have proliferated in the last two decades.

## **1.2 CURRENT ISSUES RELATED TO CAFOS**

AFOs (including CAFOs) produce and manage large amounts of animal waste, most in the form of manure. USDA estimates that 710 billion pounds (322 million metric tons) of "as excreted" manure were generated in 1997 from major livestock and poultry operations. Despite the existing ELG and NPDES regulations that define CAFOs and regulate their discharges, the management of animal wastes at AFOs has continued to be associated with environmental problems, including large spills of manure, fish kills, and outbreaks of *Pfiesteria*. In addition, industry changes in recent years may contribute to and exacerbate the problems caused by releases of manure from AFOs. EPA is revising the existing regulations with the following goals:

- To address persistent reports of discharge and runoff of manure and manure nutrients from CAFOs;
- To update the existing regulations to reflect structural changes in the animal production industries over the last few decades; and
- To improve the effectiveness of the CAFO regulations in protecting or restoring water quality.

Below we summarize the potential environmental impacts of manure releases from AFOs, and outline the recent industry changes that may exacerbate these impacts.

### **1.2.1 Potential Environmental Impacts of CAFOs**

Manure management practices at AFOs can include storage in piles or in open waste lagoons, followed by land application to agricultural fields as fertilizer. While some discharges from regulated CAFOs are governed as point sources, unregulated releases of manure from waste piles or lagoons and over-application of manure to agricultural lands can also affect nearby surface and groundwater. National and local studies have confirmed the presence of manure pollutants in surface waters. Once contaminants from manure have reached surface waters they can cause a variety of ecological and human health problems, including water quality impairments, ecological impacts, and human health effects from recreational exposure or from contaminated drinking water.

### **1.2.1.1 Water Quality Impairments**

EPA's *National Water Quality Inventory: 2000 Report* identifies agricultural operations, including CAFOs, as the leading contributor to identified water quality impairments in the nation's rivers, streams, lakes, ponds, and reservoirs, and the fifth leading contributor to identified water quality impairments in the nation's estuaries.<sup>3</sup> The report also identifies the key pollutants and stressors that impair the nation's waters. Among the most problematic pollutants are several - including pathogens, nutrients, sediment/siltation, metals, and oxygen depleting substances - that are associated commonly, although not exclusively, with animal feeding operations.<sup>4</sup>

### **1.2.1.2 Ecological Impacts**

The most dramatic ecological impacts associated with manure pollutants in surface waters are massive fish kills. Incomplete records indicate that every year dozens of fish kills associated with AFOs result in the deaths of hundreds of thousands of fish. In addition, manure pollutants such as nutrients and suspended solids can seriously disrupt aquatic systems by over-enriching water (in the case of nutrients) or by increasing turbidity (in the case of solids). Excess nutrients cause fast-growing algae blooms that reduce the penetration of sunlight in the water column, and reduce the amount of available oxygen in the water, reducing fish and shellfish habitat and affecting fish and invertebrates. Manure pollutants can also encourage the growth of toxic organisms, including *Pfiesteria*, which has been associated with fish kills and fish disease events. Reduction in biodiversity due to animal feeding operations has also been documented; for example, a study of three Indiana stream systems found fewer fish and more limited diversity of fish species downstream of CAFOs than were found downstream of study reference sites.

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<sup>3</sup> EPA prepares this report every two years, as required under Section 305(b) of the Clean Water Act. It summarizes State reports of water quality impairment and the suspected sources and causes of such impairment.

<sup>4</sup> The *National Water Quality Inventory: 2000 Report* notes that the agricultural sector contributes to the impairment of at least 129,000 river miles, 3.2 million lake acres, and over 2,800 square miles of estuary. Forty-eight states and tribes reported that agricultural activities contributed to water quality impacts on rivers, 40 states identified such impacts on lakes, ponds, and reservoirs, and 14 states reported such impacts on estuaries. Animal feeding operations are only a subset of the agriculture category, but 29 states specifically identified animal feeding operations as contributing to water quality impairment.



### **1.2.1.3 Human Health Effects**

Manure contains over 100 human pathogens; contact with some of these pathogens during recreational activities in surface water can result in infections of the skin, eye, ear, nose, and throat. Eutrophication due to excess nutrients can also promote blooms of a variety of organisms that are toxic to humans either through ingestion or contact. This includes the dinoflagellate *Pfiesteria piscicida*. While *Pfiesteria* is primarily associated with fish kills and fish disease events, the organism has also been linked with human health impacts through dermal exposure. Finally, even with no visible signs of algae blooms, shellfish such as oysters, clams and mussels can carry toxins produced by some types of algae in their tissue. These can affect people who eat contaminated shellfish.

Contaminants originating from manure pollutant loadings, including nitrogen, pathogens, and algae (whose growth can be stimulated by manure nutrient loadings), can also affect human health through drinking water sources and can result in increased drinking water treatment costs. For example, nitrogen in manure can be transported to drinking water as nitrates, which are associated with human health risks. EPA has identified nitrate as the most widespread agricultural contaminant in drinking water wells. Algae blooms triggered by nutrient pollution can affect drinking water by clogging treatment plant intakes, producing objectionable tastes and odors, and reacting with the chlorine used to disinfect drinking water to produce harmful chlorinated byproducts (e.g., trihalomethanes).

### **1.2.1.4 Air Emissions**

CAFOs are also sources of air pollutants. Animal feeding operations generate various types of animal wastes, including manure (feces and urine), waste feed, water, bedding, and dust, which can become airborne or generate emissions. Air emissions occur as a result of manure decomposition throughout the process of waste management and treatment. The rate at which emissions are generated varies as a result of a number of operational variables (e.g., animal species, type of housing, waste management system) and weather conditions (e.g., temperature, humidity, wind, time of release). Chapter 13 of EPA's Technical Development Document provides further discussion and references relating to air emissions from CAFOs.

## **1.2.2 Recent Industry Trends**

Since EPA promulgated the existing ELG and NPDES regulations governing CAFOs in the 1970s, a number of trends in the livestock and poultry industries have influenced the nature of pollution from AFOs and the potential for contamination of surface and groundwater. These trends include a combination of industry growth and concentration of animals on fewer, larger farms; location of farms closer to population centers; and advances in farm production practices and waste

management techniques. The changes in the industry have limited the effectiveness of the current regulations that define and govern releases from CAFOs.

### **1.2.2.1 Increased Production and Industry Concentration**

U.S. livestock and poultry production has risen sharply since the 1970s, resulting in an increase in the amount of manure and wastewater generated annually. The Census of Agriculture reports 1997 turkey sales of 299 million birds, compared to 141 million sold in 1978. Sales of broilers increased to 6.4 billion in 1997 from 2.5 billion in 1974.<sup>5</sup> Red meat production also rose during the 1974-1997 period; the number of hogs and pigs sold in 1997 totaled 142.6 million, compared to 79.9 million in 1974.

As production has increased, the U.S. livestock and poultry sectors have also consolidated animal production into a smaller number of larger-scale, highly specialized operations that concentrate more animals (and manure) in a single location. At the same time, significant gains in production efficiency have increased per-animal yields and the rate of turnover of animals between farm and market. These large AFOs can present considerable environmental risks because of the large amount of manure they produce and because they often do not have an adequate land base to dispose of the manure through land application. As a result, large facilities must incur the risks associated with storing significant volumes of manure, attempt to maximize the application of manure to the limited land they have available, or arrange for the use of manure on other farms. By comparison, smaller AFOs manage fewer animals and tend to concentrate less manure at a single location. These operations are more likely to have sufficient cropland and fertilizer needs to land apply manure nutrients generated at a livestock or poultry business.

### **1.2.2.2 Location of Animal Operations Closer to Consumer Markets**

Since the 1970s, the combined forces of population growth and re-location of operations closer to consumer markets and processing sectors have resulted in more AFOs located near densely populated areas. Surface waters in these areas face additional stresses from urban runoff and other point sources. The proximity of large AFOs to human populations thus increases the potential for human health impacts and ecological damage if manure or wastewater at AFOs is improperly discharged.

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<sup>5</sup> This more than two-fold increase in the number of broilers raised annually signals the need to review the existing CAFO regulations, which effectively do not cover broiler operations since virtually no such operations use wet manure management systems.

### **1.2.2.3 Advances in Agriculture Production Practices to Manage and Dispose Manure**

Continued research by USDA, state agencies and universities has led to advances in technologies and management practices that minimize the potential environmental degradation attributable to discharge and runoff of manure and wastewater. Today, there are many more practicable options to properly collect, store, treat, transport, and utilize manure and wastewater than there were in the 1970s, when the existing regulations were instituted. As a result, current regulations do not reflect the full range of management practices and technologies that may be implemented to achieve greater protection of the environment (e.g., by more effectively treating certain constituents present in animal manure or by converting manure into a more marketable form). In addition, during the time since promulgation of the existing regulation, certain practices have proven to be relatively less protective of the environment. There is documented evidence that lagoons may leak if not properly maintained, and evidence of over-application of manure and nutrient saturation of soils in some parts of the country.

## **1.3 REVISIONS TO CAFO REGULATIONS**

In response to persistent reports of environmental problems, and to changes in the industries and technologies associated with AFOs, EPA is revising both the NPDES regulations for CAFOs and the ELG regulations for feedlots. The revisions to the NPDES regulations for CAFOs affect which animal feeding operations are defined as CAFOs and are therefore subject to the NPDES permit program. Changes to the ELG regulations for feedlots affect which technology-based requirements will apply to certain CAFOs. Additional detail on the revisions to the NPDES and ELG regulations is provided below.

### **1.3.1 Changes to NPDES Regulations**

EPA's revised rule retains some of the basic elements of the existing structure for determining which AFOs are CAFOs, but with important exceptions for large facilities (see Exhibit 1-2 for the size standards for Large, Medium, and Small CAFOs).<sup>6</sup> Under the revised regulations, all large CAFOs have a mandatory duty to apply for an NPDES permit. This change has two important effects. First, it removes ambiguity over whether a large facility needs an NPDES permit, even if it discharges only as the result of a large storm event. Second, large poultry operations are covered, regardless of the type of watering system used or whether the litter is managed in wet or dry form. In addition, the revised CAFO definition includes size standards for operations that stable or confine immature dairy cattle or veal calves, cow/calf pairs, or swine weighing less than 55 pounds, thus extending the regulations to address stand-alone immature swine or heifer operations. In the rare

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<sup>6</sup> Note that the new size standards are specified with respect to the number of animals confined; they no longer reference "animal units."

event that a large CAFO has no potential to discharge, the new requirements provide a process for a demonstration to that effect, in lieu of obtaining a permit.

<b>Exhibit 1-2</b>			
<b>SIZE STANDARDS FOR LARGE, MEDIUM, AND SMALL CAFOS</b>			
<b>Sector</b>	<b>Large</b>	<b>Medium<sup>1</sup></b>	<b>Small<sup>2</sup></b>
Mature Dairy Cattle	more than 700	200 - 700	less than 200
Veal Calves	more than 1,000	300 - 1,000	less than 300
Cattle or Cow/Calf Pairs	more than 1,000	300 - 1,000	less than 300
Swine (weighing over 55 pounds)	more than 2,500	750 - 2,500	less than 750
Swine (weighing less than 55 pounds)	more than 10,000	3,000 - 10,000	less than 3,000
Horses	more than 500	150 - 500	less than 150
Sheep or Lambs	more than 10,000	3,000 - 10,000	less than 3,000
Turkeys	more than 55,000	16,500 - 55,000	less than 16,500
Chickens (liquid manure handling systems)- includes Laying Hens	more than 30,000	9,000 - 30,000	less than 9,000
Chickens Other than Laying Hens (other than liquid manure handling)	more than 125,000	37,500 - 125,000	less than 37,500
Laying Hens (other than liquid manure handling)	more than 82,000	25,000 - 82,000	less than 25,000
Ducks (dry operations)	more than 30,000	10,000 - 30,000	less than 10,000
Ducks (wet operations)	more than 5,000	1,500 - 5,000	less than 1,500
<sup>1</sup> Must also meet one of two criteria to be defined as a CAFO.			
<sup>2</sup> Must be designated by EPA or the State permit authority.			

The factors that lead smaller AFOs to be classified as CAFOs are largely unchanged. As with the existing regulations, medium-size AFOs are defined as CAFOs only if they meet one of two specific criteria governing the method of discharge:

- Pollutants are discharged into waters of the United States through a manmade ditch, flushing system, or other similar man-made device; or

- Pollutants are discharged directly into waters of the United States that originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the confined animals.

Similarly, small facilities are considered CAFOs only if they are designated as such by EPA or the State NPDES permit authority. Such designation must be based on a determination that a facility is a significant contributor of pollutants to waters of the United States. On identical grounds, medium-size operations that are not CAFOs by definition may also be designated as CAFOs.

Under the new regulations, all CAFOs, regardless of size, must be covered by an NPDES permit and are required to develop and implement a nutrient management plan. Such plans must identify practices necessary to demonstrate compliance with the effluent limitation guideline (if applicable), and include requirements to land apply manure and wastewater in a manner consistent with the appropriate agricultural utilization of nutrients.

### 1.3.2 Changes to ELGs

As with the previous CAFO regulations, EPA's revised effluent guidelines will apply only to large CAFOs; for other permitted facilities, technology-based discharge limits will continue to be established on the basis of the permit writer's best professional judgment. The revised regulations, however, introduce differing requirements for existing sources and new sources. The key features of these requirements are as follows:

- **Existing Sources** — In the case of existing sources, the effluent limitation guideline will continue to prohibit the discharge of manure and other process wastewater from the production area.<sup>7</sup> An exception to this prohibition allows the discharge of process wastewater in overflow whenever rainfall causes an overflow from a facility designed, constructed, operated, and maintained to contain all process wastewater and runoff from a 25-year, 24-hour (or more severe) rainfall event. The ELG also establishes certain best management practices (BMPs) that apply to the production area. In addition, the ELG requires Large CAFOs to prepare and implement a site-specific nutrient management plan that establishes manure application rates for each field based on the technical standards for nutrient management established by the permitting authority's director. Large CAFOs also must implement certain other BMPs that apply to the land application area.<sup>8</sup>

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<sup>7</sup> The production area of an AFO includes the animal confinement area, the litter or manure storage area, the raw materials storage area, and the waste containment area.

<sup>8</sup> These requirements apply to any land under the control of the owner or operator of the production area — whether it is owned, rented, or leased — to which manure and wastewater from

- **New Sources** — For new sources in the beef and dairy sector, the requirements for managing the production area are the same as for existing sources. In contrast, the discharge of process wastewater from the production area of new sources in the swine, veal, and poultry sectors is prohibited, except for facilities designed to contain all process wastewater and the direct precipitation and runoff from a 100-year, 24-hour rainfall event. The land application requirements for new sources are identical to those for existing sources.

### 1.3.3 Number of Regulated Operations

EPA has estimated the likely number of AFOs that would be regulated under the revised CAFO rules. EPA analyzed data from the USDA's 1997 Census of Agriculture to identify AFOs and CAFOs. EPA first determined the number of operations that raise animals under confinement by using available data on the total number of livestock and poultry facilities. Next, EPA determined the number of CAFOs based on the number of facilities that discharge or have the potential to discharge to U.S. waters and which meet the minimum size thresholds (i.e., number of animals) defined by the revised regulations. Exhibit 1-3 shows the number of CAFOs estimated to be subject to the new rules.

## 1.4 ANALYTIC METHODS AND RESULTS

To determine the economic benefits of the revised regulations, EPA performed several analyses of expected changes in environmental quality that would likely result from reduced AFO pollution, focusing solely on the impact of the revised standards for Large CAFOs. The detailed analyses addressed the following issues:

- **Improvements in Water Quality and Suitability for Recreational Activities:** this analysis estimates the economic value of improvements in inland surface water quality that would increase opportunities for recreational boating, fishing, and swimming;

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the production area is or may be applied.

Exhibit 1-3				
ESTIMATED NUMBER OF CAFOS SUBJECT TO REVISED REGULATIONS*				
Production Sector	Currently Regulated	Regulated Under New Rule		
		Large CAFOs	Medium CAFOs	Total
Beef	1,940	1,766	174	1,940
Dairy	3,399	1,450	1,949	3,399
Heifers	0	242	230	472
Veal	0	12	7	19
Swine	5,409	3,924	1,485	5,409
Layers	433	1,112	50	1,162
Broilers	683	1,632	520	2,152
Turkeys	425	388	37	425
Horses	195	195	0	195
Ducks	21	21	4	25
<b>Total</b>	<b>12,505</b>	<b>10,742</b>	<b>4,456</b>	<b>15,198</b>
* AFOs that stable or confine animals in different sectors are counted more than once.				

- **Reduced Incidence of Fish Kills:** this analysis estimates the economic value of a potential reduction in the number of fish kills caused by AFO-related waste;
- **Improved Commercial Shellfishing:** this analysis characterizes the impact of pollution from AFOs on access to commercial shellfish growing waters, and values the potential increase in commercial shellfish harvests that may result from improved control of that pollution;
- **Reduced Contamination of Private Wells:** this analysis examines the impact of the revised regulations on groundwater quality, and values predicted improvements in the quality of aquifers that supply private wells;
- **Reduced Contamination of Animal Water Supplies:** this analysis characterizes the impact of pollution from AFOs on livestock mortality, and values the potential impact of the revised regulations in reducing mortality rates;

- **Reduced Eutrophication of Estuaries:** this analysis examines the impact of the revised regulations on nutrient loadings to selected estuaries, and presents a case study illustrating the potential economic benefits of the anticipated reduction in such loads; and
- **Reduced Water Treatment Costs:** this analysis examines the revised regulations' beneficial effect on source water quality and the consequent reduction in treatment costs for public water supply systems.

Exhibit 1-4 summarizes the results of these studies for the final rule, reflecting the following requirements: zero discharge from a facility designed, maintained, and operated to hold manure, litter, and other process wastewater, including direct participation and runoff from a 25-year, 24-hour rainfall event; implementation of feedlot best management practices, including storm water diversions; lagoon and pond depth markers; periodic inspections; elimination of manure application within 100 feet of any surface water, tile drain inlet, or sinkhole; compliance with mortality-handling, nutrient management planning, and record keeping guidelines; and phosphorus-based agronomic application rates. The exhibit also presents analytic results for the final rule assuming nitrogen-based agronomic application rates, rather than the proposed phosphorus-based standard. It is important to note that these results are not intended to represent the total value of all benefits associated with a reduction in AFO pollutants; they include only the subset of benefits that is addressed by EPA's analyses. Moreover, EPA's analyses generally take a conservative approach to quantifying benefits; therefore, the results are likely to reflect conservative estimates of the specific benefits that EPA has examined.

EPA also considered how today's rule would affect the amount and form of compounds released to air, as well as the energy that is required to operate the CAFO. In addition to the water quality impacts and benefits discussed above, EPA's evaluated non-water quality environmental impacts, including changes in air emissions from CAFOs and changes in energy use at CAFOs. EPA's estimates of changes in air emissions and energy use are described in more detail in the *Technical Development Document*. In addition, during the rulemaking, EPA evaluated a number of regulatory options and, as part of those analyses, also considered the potential air quality benefits associated with changes in ammonia emissions. For further discussion of those analyses, refer to Chapter 13 of the *Technical Development Document* and Section 22 of the rulemaking record.

## 1.5 ASSESSMENT OF DATA USED TO ESTIMATE BENEFITS

The majority of the data EPA used to estimate the environmental and economic benefits associated with the revised standards for CAFOs are from existing sources. As defined in the Office of Water 2002 Quality Management Plan (USEPA 2002), existing (or secondary) data are data that were not directly generated by EPA to support the decision at hand. Existing data were used to identify animal feeding operations that are defined as CAFOs and subject to the NPDES permit program under the final rule, and to model the effects of changes to the effluent guidelines for feedlots.



**Exhibit 1-4**

**ESTIMATED ANNUALIZED BENEFITS OF THE REVISED  
CAFO REGULATIONS UNDER ALTERNATE DISCOUNT RATES<sup>1</sup>  
(2001 dollars, millions)**

<b>Benefits Category</b>	<b>Phosphorus-Based</b>			<b>Nitrogen-Based</b>		
	<b>3%</b>	<b>5%</b>	<b>7%</b>	<b>3%</b>	<b>5%</b>	<b>7%</b>
Improved Surface Water Quality	\$166.2 - \$298.6	\$166.2 - \$298.6	\$166.2 - \$298.6	\$102.4 - \$182.6	\$102.4 - \$182.6	\$102.4 - \$182.6
Reduced Incidence of Fish Kills	\$0.1	\$0.1	\$0.1	\$0.0 - \$0.1	\$0.0 - \$0.1	\$0.0 - \$0.1
Improved Commercial Shell Fishing	\$0.3 - \$3.4	\$0.3 - \$3.4	\$0.3 - \$3.4	\$0.1 - \$2.0	\$0.1 - \$2.0	\$0.1 - \$2.0
Reduced Contamination of Private Wells	\$45.7	\$37.1	\$30.9	\$49.3	\$40.0	\$33.3
Reduced Contamination of Animal Water Supplies	\$5.3	\$5.3	\$5.3	\$4.7	\$4.7	\$4.7
Reduced Eutrophication of Estuaries	not monetized	not monetized	not monetized	not monetized	not monetized	not monetized
Albemarle-Pamlico Case Study	\$0.2	\$0.2	\$0.2	\$0.1	\$0.1	\$0.1
Reduced Water Treatment Costs	\$1.1 - \$1.7	\$1.1 - \$1.7	\$1.1 - \$1.7	\$0.7 - \$1.0	\$0.7 - \$1.0	\$0.7 - \$1.0
All Categories <sup>2</sup>	\$218.9 + [B] - \$355.0 + [B]	\$210.3 + [B] - \$346.4 + [B]	\$204.1 + [B] - \$340.2 + [B]	\$157.3 + [B] - \$239.8 + [B]	\$148.0 + [B] - \$230.5 + [B]	\$141.3 + [B] - \$223.8 + [B]

<sup>1</sup> The analysis accounts for benefits associated with the revised regulations for Large CAFOs only. The impact of revised standards on Medium CAFOs is not included.

<sup>2</sup> Discrepancies between these totals and the sum of the figures in each column are due to rounding. Values are rounded to the nearest \$100 thousand.  
[B] Represents non-monetized benefits of the rule.

In keeping with the graded approach to quality management embodied in the quality management plan, EPA must assess the quality of existing data relative to their intended use. The procedures EPA used to assess existing data for use in estimating the benefits associated with the revised standards for CAFOs varied with the specific type of data. In general, EPA's assessment included:

- Reviewing a description of the existing data that explains how the data were collected or produced (e.g., who collected and uses the data; what data were collected; when, why, and how the data were collected; whether the data were gathered as part of a one-time or long-term effort; and the level of review the data have received from others);
- Specifying the intended use of the existing data relative to the CAFO final rule;
- Developing a rationale for accepting data from the source, either as a set of acceptance criteria or as a narrative discussion; and
- Describing any known data limitations and their impact on EPA's use.

Brief descriptions of the data and their limitations are presented later in this document, as each data source is introduced.

In searching for existing data sources and determining their acceptability, EPA generally used a hierarchical approach designed to identify and utilize data with the broadest representation of the industry sector or topic of interest. EPA began by searching for national-level data from surveys and studies by USDA and other federal agencies. When survey or study data did not exist, EPA considered other types of data from federal agencies.

Where national data did not exist, as the second tier, EPA searched for data from land grant universities. Such data are often local or regional in nature. EPA assessed the representativeness of the data relative to a national scale before deciding to use the data. When such data came from published sources, EPA gave greater consideration to peer-reviewed professional journals than to publications lacking a formal review process.

The third tier was data supplied by industry. Prior to publication of proposed changes to the rule, EPA requested data from a variety of industry sources, including trade associations and large producers. The level of review applied to data supplied by industry depended on the level of supporting detail that was provided. For example, if the industry supplied background information regarding how the data were collected, such as the number of respondents and the total number of potential respondents, EPA reviewed the results, comparing them to data from other potential sources to determine their suitability for use in this rulemaking. If the data provided by industry originated from an identifiable non-industry source (e.g., a state government agency),

EPA reviewed the original source before determining the acceptability of the data. In a limited number of instances, EPA conducted site visits to substantiate information supplied by industry. In contrast, data supplied by industry without any background information were given much less weight and generally were not used by EPA. Further, some data that were supplied by industry prior to the proposal were included in the proposal for comment. In the absence of any negative comments, such data were relied on to a greater extent than data submitted by industry during the comment period itself.

## **1.6 ORGANIZATION OF REPORT**

The remainder of this report presents EPA's analysis of the benefits of the revised CAFO regulations. Specifically:

- Chapter 2 provides a detailed description of the potential impacts of CAFOs on environmental quality and human health;
- Chapter 3 describes the range of benefits that would result from decreased CAFO loadings, and outlines EPA's general approach to quantifying and valuing the subset of benefits analyzed;
- Chapter 4 assesses the value of changes in surface water quality that would result from the estimated reduction in CAFO loadings arising from the final regulation, focusing on changes in the quality of freshwater resources that would improve their suitability for recreational activities;
- Chapter 5 assesses the value of a reduced incidence of fish kills attributable to pollution from CAFOs, as estimated under the final rule;
- Chapter 6 assesses the value of improved commercial shellfishing resulting from decreased CAFO loadings, as estimated under the final rule;
- Chapter 7 assesses the value of reduced contamination of private wells associated with reductions in the pollution of groundwater by CAFOs;
- Chapter 8 estimates the economic benefits associated with reductions in livestock mortality that are predicted to occur under the final rule as a result of reduced contamination of animal water supplies;
- Chapter 9 examines the impact of the revised regulations on nutrient loadings to selected estuaries, and presents a case study illustrating the potential economic benefits of the anticipated reduction in such loads;

- Chapter 10 evaluates the impact of the revised regulations on source water quality and estimates the subsequent reduction in treatment costs for public water supply systems; and
- Chapter 11 summarizes the benefits analysis for the final rule.

## 1.7 REFERENCES

Kellogg, Robert L. 2002. *Profile of Farms with Livestock in the United States: A Statistical Summary*. U.S. Department of Agriculture, Natural Resources Conservation Service.

Kellogg, Robert L. et al. 2000. *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States*. U.S. Department of Agriculture, Natural Resources Conservation Service and Economic Research Service. December.

USDA/USEPA (U.S. Department of Agriculture and U.S. Environmental Protection Agency). 1999. *Unified National Strategy for Animal Feeding Operations*, Section 4.2. Available on EPA's web site at: <http://www.epa.gov/owm/finafost.htm#1.0>.

USEPA. 2002. Office of Water Quality Management Plan. April 2002. EPA 821-X-02-001.

## POTENTIAL IMPACTS OF AFOS ON ENVIRONMENTAL QUALITY AND HUMAN HEALTH

## CHAPTER 2

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Animal manure, the primary cause of pollution related to AFOS, contains a variety of pollutants that can cause environmental degradation, particularly when released to surface waters in large quantities.<sup>1</sup> Documented releases from AFOS have been associated with a number of adverse human health and ecological impacts, including fish kills, disease outbreaks, and degradation of water quality and aquatic life.

EPA's *National Water Quality Inventory: 2000 Report* identifies agricultural operations, including CAFOs, as the leading contributor to identified water quality impairments in the nation's rivers, streams, lakes, ponds, and reservoirs, and the fifth leading contributor to identified water quality impairments in the nation's estuaries.<sup>2</sup> The report also identifies the key pollutants and stressors that impair the nation's waters. Among the most problematic pollutants are several - including pathogens, nutrients, sediment/siltation, metals, and oxygen depleting substances - that are associated commonly, although not exclusively, with animal feeding operations.<sup>3</sup>

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<sup>1</sup> This document uses the term manure to refer to both "solid" manure and urine, since these wastes are typically managed together. Additional animal wastes associated with AFOS (e.g., hair, feathers, bedding material and carcasses) are identified separately in the discussion.

<sup>2</sup> EPA prepares this report every two years, as required under Section 305(b) of the Clean Water Act. It summarizes State reports of water quality impairment and the suspected sources and causes of such impairment.

<sup>3</sup> The *National Water Quality Inventory: 2000 Report* notes that the agricultural sector contributes to the impairment of at least 129,000 river miles, 3.2 million lake acres, and over 2,800 square miles of estuary. Forty-eight states and tribes reported that agricultural activities contributed to water quality impacts on rivers, 40 states identified such impacts on lakes, ponds, and reservoirs, and 14 states reported such impacts on estuaries. Animal feeding operations are only a subset of the agriculture category, but 29 states specifically identified animal feeding operations as contributing to water quality impairment.

The animal waste management practices and pollutant transport pathways that can lead to contamination of surface waters are well known. Animal wastes at AFOs are typically managed by land application and/or storage in waste piles or lagoons. Land application and storage of manure are centuries-old farming practices. In small or low-density farming operations these methods pose minimal pollution potential. AFOs, however, manage large amounts of manure in a concentrated area. Under these circumstances, the following waste management failures pose an increased potential for pollution:

- **Over-application of manure:** While land application of manure can provide valuable nutrients to soil and crops, the capacity of soil and crops to absorb nutrients over any given period is limited. Excess manure applied to cropland can damage crops and soil, and is more likely to run off into surface waters or be released to air through volatilization or erosion (for example, through spray application).
- **Runoff from uncovered manure piles:** Manure piles are frequently used for temporary storage of animal wastes. Precipitation may wash pollutants from uncovered manure piles into nearby surface waters.
- **Lagoon failures:** AFOs frequently store large quantities of manure in lagoons prior to land application or other disposal. While lagoons are designed to prevent the release of wastes into the environment, they are subject to various types of failure, including spills due to overfilling; washouts in floods; liner failures; failures of dikes, pipes, or other above-ground structures; and accidental and intentional operator-related releases.

This chapter briefly describes the pathways, pollutants, and environmental and human health effects associated with releases from AFOs. More detailed information is available in *Environmental Assessment of the Proposed Effluent Limitation Guidelines for Concentrated Animal Feeding Operations*.

## **2.1 PATHWAYS FOR THE RELEASE OF POLLUTANTS FROM AFOS**

Pollutants in animal wastes can reach surface waters by several pathways, including overland discharge, migration through groundwater, and atmospheric deposition. The most common pathway is overland discharge, which includes surface runoff (i.e., land-applied or piled manure that is washed into surface waters by rain), soil erosion, and acute events such as spills or impoundment failures. Contamination can also occur when pollutants leach through soil into groundwater and then to surface water through groundwater recharge. In addition, airborne pollutants created by volatilization or by spray-application of manure to land can contaminate surface water through atmospheric deposition. Exhibit 2-1 illustrates the various pathways by which AFO releases can

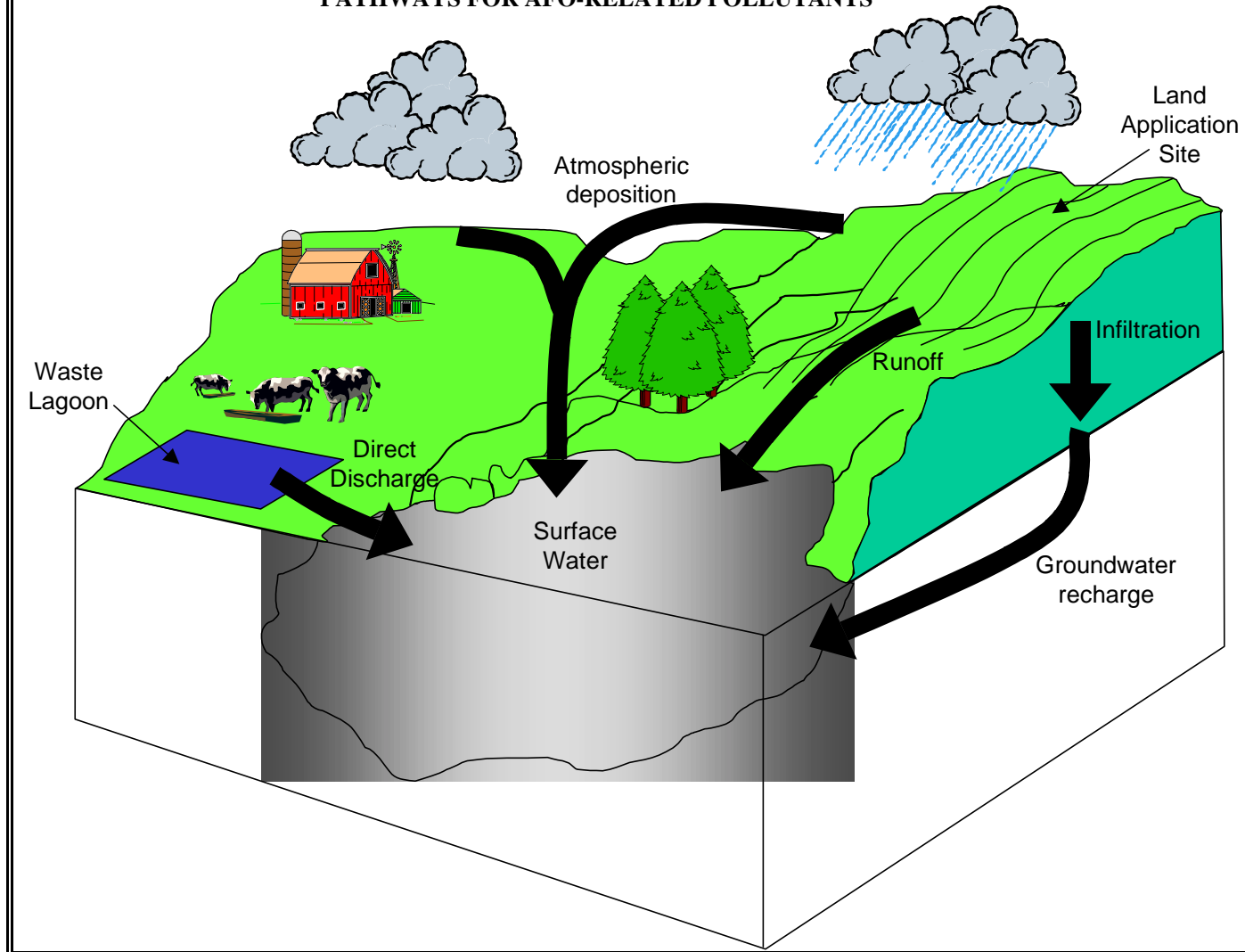
affect surface waters and groundwater. The following discussion describes these pathways in greater detail.

### **2.1.1 Overland Discharge**

Contamination from manure often reaches surface water through overland discharge; that is, by flowing directly into surface waters from land application sites or lagoons. There are three distinct types of overland discharge: surface runoff, soil erosion, and direct discharge of manure to surface water during acute events. For example, a single flood event might include lagoon "washouts," soil erosion and surface runoff. This section describes the various types of overland discharge in more detail.

Exhibit 2-1

PATHWAYS FOR AFO-RELATED POLLUTANTS





### **2.1.1.1 Surface Runoff**

Surface runoff occurs whenever rainfall or snowmelt is not absorbed by soil and flows overland to surface waters.<sup>4</sup> Runoff from land application sites or manure piles can transport pollutants to surface waters, especially if rainfall occurs soon after application, if manure is over-applied, or if it is misapplied.<sup>5</sup> The potential for runoff of animal wastes varies considerably with climate, soil conditions, and management practices. For example, manure applied to saturated or frozen soils is more likely to runoff the soil surface (ODNR, 1997). Other factors that promote runoff to surface waters are steep land slope, high rainfall, low soil porosity or permeability, and close proximity to surface waters. Surface runoff is a particularly significant transport mechanism for water soluble pollutants, including nitrogen compounds. Runoff can also carry solids.

Runoff of manure pollutants has been identified as a factor in a number of documented impacts from AFOs, including hog, cattle, and chicken operations. For example, in 1994, multiple runoff problems were cited for a hog operation in Minnesota, and in 1996 runoff from manure spread on land was identified at hog and chicken operations in Ohio. In 1996 and 1997, runoff problems were identified for several cattle operations in numerous counties in Minnesota (CWAA, 1998; ODNR, 1997).

### **2.1.1.2 Soil Erosion**

In addition to simple surface runoff, pollutants from animal wastes can enter surface water through erosion, in which the soil surface itself is worn away by the action of water or wind. Soil erosion often occurs in conjunction with surface runoff as part of rainfall events, but it represents a transport mechanism for additional pollutants that are strongly sorbed (i.e., chemically bound) to soils. The most important of these pollutants is phosphorus. Because of its tendency to sorb to soils, many agricultural phosphorus control measures focus on soil erosion control. However, soils do not have infinite adsorption capacity for phosphorus or other pollutants, and dissolved pollutants (including phosphates) can still enter waterways through runoff even if soil erosion is controlled (NRC, 1993).

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<sup>4</sup> Surface discharges can also result from direct contact between confined animals and surface waters. Certain animals, particularly cattle, will wade into the surface waters to drink, and will often urinate and defecate there as well. This practice is now restricted for CAFOs, but may still occur at other types of AFOs.

<sup>5</sup> Experiments show that for all animal wastes, application rates have a significant effect on runoff concentrations of pollutants. See Daniel *et al.*, 1995.

In spite of control efforts, soil erosion remains a serious challenge for agriculture. For example, in 1997 the USDA Natural Resources Conservation Service (NRCS) reviewed the connection between manure production, soil erosion, and water quality in a watershed in South Carolina. NRCS calculated that soil erosion from the 13,000 acres of cropland in the watershed ranged from 9.6 to 41.5 tons per acre per year. The report further found that manure and erosion-related pollutants such as bacteria, nutrients, and sediment are the primary contaminants affecting streams and ponds in the watershed (USEPA, 1997).

### 2.1.1.3 Acute Events

In addition to surface runoff and erosion, acute events such as spills, floods, or other lagoon or application failures can affect surface waters. Unlike runoff and erosion, which generally affect land-applied wastes, acute events frequently affect waste management lagoons. Spills can result from mechanical malfunctions (e.g., pump failures, manure irrigation gun malfunctions, and failures in pipes or retaining walls), overfilling, or washouts during flood events. There are even indications that some operators discharge wastes into surface waters deliberately in order to reduce the volume of waste in

overfull lagoons (CWAA, 1998). Acute events frequently result in large waste discharges and are often associated with immediate ecological effects such as fish kills. In addition to immediate fish kills, large releases can be linked with eutrophication, sedimentation, and the growth of pathogens. All of these impacts can also cause acute mortality in fish and other aquatic species.

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#### ***Catastrophic Release of Manure: New River, North Carolina, 1995***

*On June 21, 1995, a breach in the dike of a 30 million gallon hog waste lagoon discharged over 25 million gallons of waste into tributaries of the New River in Onslow County, North Carolina.*

*Within a week of the event, North Carolina state officials estimated that roughly 2,600 fish were destroyed, though monitoring indicated that oxygen levels had recovered in the river within a week of the event. JoAnne Burkholder, a North Carolina State University marine scientist, noted that the initial waste deluge probably smothered many fish. Others were killed more slowly by declining oxygen levels and the toxic effects of ammonia and bacteria in the water.*

*Two days after the spill scientists sampling in some of the affected areas found ammonia levels of about 20 times the lethal limit for most fish.*

*Though oxygen levels recovered rapidly, Burkholder noted that it could take years for the upper New ecosystem to fully recover and support the range of fish, clams and other creatures that existed before the spill. In addition to immediate problems, longer term problems caused by the breach would include rains churning up settled pollution and potential algae blooms.*

*State environmental officials also confirmed that high levels of fecal coliform bacteria were detected in the river, and Onslow County health officials posted warnings in public recreation areas to prevent people from swimming. According to local newspaper reports, in some places fecal coliform levels were 10,000 times the state standard for swimming.*

***Sources:*** Warrick and Stith, 1995b; Warrick 1995b, 1995c, 1995d.

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### **2.1.2 Leaching to Groundwater**

Pollutants from animal waste can migrate to groundwater and subsequently contaminate surface waters through the process of "groundwater recharge," in which hydrological connections between aquifers and surface waters allow transfer of water (and pollutants). Groundwater contamination itself can result from leaching of land-applied pollutants into the soil, or from leaking lagoons. Although most lagoons are lined with clay or are designed to be "self-sealed" by manure solids that prevent infiltration of pollutants into groundwater, these methods are not always effective. For example, a survey of hog and poultry lagoons in the Carolinas found that the contents of nearly two-thirds of the 36 lagoons sampled had leaked into the groundwater (Meadows, 1995). Similarly, clay-lined lagoons can crack or break as they age, and are susceptible to burrowing worms. In a three-year study of clay-lined swine lagoons on the Delmarva Peninsula, researchers found that leachate from lagoons located in well-drained loamy sand adversely affected groundwater quality (Ritter *et al.*, 1990).

Surface water contamination from groundwater is most likely to occur in areas with high soil permeability and shallow water tables, and is most likely to involve water soluble contaminants such as nitrate (Smith *et al.*, 1997). Overall, the potential for contamination by this pathway may be considerable. For example, in the Chesapeake Bay watershed, the USGS estimates that about half of the nitrogen loads from all sources to non-tidal streams and rivers originates from groundwater (ASCE, 1998). In addition, about 40 percent of the average annual stream flow in the United States results from groundwater recharge (USEPA, 1993).

### **2.1.3 Discharges to the Air and Subsequent Deposition**

Discharges to the air from AFOs include both volatile pollutants (e.g., ammonia and various by-products of manure decomposition) and particulate matter from dried manure, feed, hair, and feathers. The degree of volatilization of pollutants from manure depends on environmental conditions and the manure management system employed. For example, spray application of manure increases the potential for volatilization, as does the practice of spreading manure on the land without incorporating it into the soil. Volatilization is also affected by climate and soil conditions, (e.g., soil acidity and moisture content), and is reduced by the presence of growing plants (Follett, 1995).

Particulate matter from manure forms an organic dust made up of dried manure, feed, and epithelial cells. These airborne particles can contain adsorbed gases, endotoxin (the toxic protoplasm liberated when a microorganism dies and disintegrates), and possibly steroids from animal waste. According to information presented to the Centers for Disease Control, at least 50 percent of the dust

emissions from swine operations are believed to be respirable and may therefore be associated with inhalation-related human health effects (Thu, 1998).<sup>6</sup>

In addition to creating the potential for air-related health effects, both volatilized pollutants and particulate matter can contaminate nearby surface waters through atmospheric deposition. Volatilization of the ammonia originating from animal waste, in particular, has been linked with atmospheric deposition of nitrogen (Lander *et al.*, 1998). While it is not clear what percentage of total deposition of pollutants can be linked to AFOs, EPA's *National Water Quality Inventory: 2000 Report* indicates that atmospheric deposition from all sources is among the leading causes of water quality impairment in estuaries, lakes, reservoirs and ponds.

## **2.2 POTENTIAL ECOLOGICAL HAZARDS POSED BY AFO POLLUTANTS**

The primary pollutants associated with animal waste are nutrients (particularly nitrogen and phosphorus), organic matter, solids, pathogens, and odorous/volatile compounds. Animal waste is also a source of salts and trace elements and, to a lesser extent, antibiotics, pesticides, and hormones. The concentration of particular pollutants in manure varies with animal species, the size, maturity, and health of the individual animal, and the composition (e.g., protein content) of animal feed.<sup>7</sup> The range of pollutants associated with manure is evident in a 1991 U.S. Fish and Wildlife Service (USFWS) report on suspected water quality impacts from cattle feedlots on Tierra Blanca Creek in the Texas Panhandle. The water quality impacts the USFWS reported included elevated concentrations of ammonia, coliform bacteria, chloride, nitrogen, and suspended solids, as well as reduced concentrations of dissolved oxygen. In addition, USFWS found elevated concentrations of the feed additives copper and zinc in creek sediment (USFWS, 1991).

The ecological impacts of animal waste releases to surface water can range from minor, temporary fluctuations in water quality (e.g., associated with limited surface runoff) to chronic degradation of ecosystems (e.g., associated with consistently poor management practices such as over-application), to dramatic impacts such as extensive fish or wildlife kills (e.g., associated with acute events such as spills and consequent oxygen depletion, increased ammonia concentrations, or toxic algae blooms). In some cases, individual pollutants associated with animal waste are the clear and direct cause of observable ecological effects. In other cases, ecological effects such as declines in aquatic populations are the result of complex systemic changes that are linked directly or indirectly to pollution from AFOs.

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<sup>6</sup> "Respirable" generally refers to particles less than 10 microns in diameter, or PM10; these particles are responsible for the majority of human health effects related to air pollution because they are small enough to travel through the nasal passage and into the lungs.

<sup>7</sup> For more detailed discussion of the pollutants associated with animal waste, see Phillips *et al.*, 1992.

Exhibit 2-2 lists the key pollutants associated with AFO waste, and notes their potential impacts. The remainder of this section describes in more detail the relationship between AFO pollutants and observed ecological effects. Section 2.3 focuses on the specific impacts of AFO pollutants on human health.

### **2.2.1 Nutrients and Eutrophication**

EPA's *National Water Quality Inventory: 2000 Report* indicates that nutrients from all sources comprise the leading stressor in impaired lakes, ponds, and reservoirs, and are among the most frequent stressors in impaired rivers, streams, and estuaries. Nutrients are naturally occurring elements that are necessary for plant growth. However, when excess nutrients enter surface waters they can stimulate overgrowth of algae and bacteria, changing ecosystems in a process called "eutrophication." In addition, nutrients (nitrogen, in particular) in high concentrations can be toxic to animals and humans.

The two nutrients of most concern related to AFOs are nitrogen and phosphorus.<sup>8</sup> Each of these elements exists in several forms in the environment, and is involved in several phases of uptake and digestion by animals and plants. This section briefly describes the processes by which nitrogen and phosphorus enter aquatic ecosystems, then discusses the process and impacts of eutrophication.

#### **2.2.1.1 Nitrogen and Nitrogen Compounds**

Nitrogen, an element essential to plant growth, moves through the environment in a series of chemical reactions known as the nitrogen cycle. Nitrogen in manure exists in both organic forms (e.g., urea) and inorganic forms (e.g., ammonium and nitrate) (NCAES, 1982). In fresh manure, 60 to 90 percent of total nitrogen is present in the organic form. Inorganic nitrogen can enter the environment by volatilizing in the form of ammonia, or through soil or water microbe processes that transform organic nitrogen to an inorganic form that can be used by plants (i.e., as fertilizer). Both ammonia and ammonium are toxic to aquatic life, and ammonia in particular reduces the dissolved oxygen in surface waters that is necessary for aquatic animals. Nitrites pose additional risks to aquatic life: if sediments are enriched with nutrients, nitrite concentrations in the water may be raised enough to cause nitrite poisoning or "brown blood disease" in fish (USDA, 1992).

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<sup>8</sup> Potassium contributes to the salinity of animal manure, which may in turn contribute salinity to surface water polluted by manure. Actual or anticipated levels of potassium in surface water and groundwater, however, are unlikely to pose hazards to human health or aquatic life. For more information see Wetzel, 1983.

Exhibit 2-2			
KEY POLLUTANTS IN ANIMAL WASTE			
Pollutant	Description of Pollutant Forms in Animal Waste	Pathways	Potential Impacts
<b>Nutrients</b>			
Nitrogen	Exists in fresh manure in organic (e.g., urea) and inorganic forms (e.g., ammonium and nitrate). Microbes transform organic nitrogen to inorganic forms that may be absorbed by plants.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Leachate into groundwater</li> <li>▶ Atmospheric deposition as ammonia</li> </ul>	<ul style="list-style-type: none"> <li>▶ Eutrophication</li> <li>▶ Animal, human health effects</li> </ul>
Phosphorus	Exists in both organic and inorganic forms. As manure ages, phosphorus mineralizes to inorganic phosphate compounds that may be absorbed by plants.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Leachate into groundwater (water soluble forms)</li> </ul>	<ul style="list-style-type: none"> <li>▶ Eutrophication</li> </ul>
Potassium	Most potassium in manure is in an inorganic form available for absorption by plants; it can also be stored in soil for future uptake.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Leachate into groundwater</li> </ul>	<ul style="list-style-type: none"> <li>▶ Increased salinity</li> </ul>
<b>Organic Compounds</b>	Carbon-based compounds in manure that are decomposed by soil and surface water micro-organisms. Creates biochemical oxygen demand, or BOD, because decomposition consumes dissolved oxygen in the water.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> </ul>	<ul style="list-style-type: none"> <li>▶ Depletion of dissolved oxygen</li> <li>▶ Reduction in aquatic life</li> <li>▶ Eutrophication</li> </ul>
<b>Solids</b>	Includes manure itself and other elements (e.g., feed, bedding, hair, feathers, and corpses).	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Atmospheric deposition</li> </ul>	<ul style="list-style-type: none"> <li>▶ Turbidity</li> <li>▶ Siltation</li> </ul>
<b>Pathogens</b>	Includes range of disease-causing organisms, including bacteria, viruses, protozoa, fungi, and algae. Some pathogens are found in manure, others grow in surface water due to increased nutrients and organic matter.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Growth in waters with high nutrient, organic materials</li> </ul>	<ul style="list-style-type: none"> <li>▶ Animal, human health effects</li> </ul>
<b>Salts</b>	Includes cations sodium, potassium, calcium, and magnesium; and anions chloride, sulfate, bicarbonate, carbonate, and nitrate.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> <li>▶ Leachate into groundwater</li> </ul>	<ul style="list-style-type: none"> <li>▶ Reduction in aquatic life</li> <li>▶ Human health effects</li> <li>▶ Soil impacts</li> </ul>
<b>Trace Elements</b>	Includes feed additives arsenic, copper, selenium, zinc, cadmium; and trace metals molybdenum, nickel, lead, iron, manganese, aluminum, and boron (pesticide ingredients).	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> </ul>	<ul style="list-style-type: none"> <li>▶ Toxicity at high levels</li> </ul>
<b>Volatile Compounds</b>	Includes carbon dioxide, methane, nitrous oxide, hydrogen sulfide, and ammonia gases generated during decomposition of waste.	<ul style="list-style-type: none"> <li>▶ Inhalation</li> <li>▶ Atmospheric deposition of ammonia</li> </ul>	<ul style="list-style-type: none"> <li>▶ Human health effects</li> <li>▶ Eutrophication</li> <li>▶ Global warming</li> </ul>
<b>Other Pollutants</b>	Includes pesticides, antibiotics, and hormones used in feeding operations.	<ul style="list-style-type: none"> <li>▶ Overland discharge</li> </ul>	<ul style="list-style-type: none"> <li>▶ <i>Impacts unknown</i></li> </ul>

A 1975 study found that up to 50 percent or more of the nitrogen in fresh manure may be in ammonia form or converted to ammonia relatively quickly once manure is excreted (Vanderholm, 1975). Ammonia is highly volatile, and ammonia losses from animal feeding operations can be considerable. In North Carolina, animal agriculture is responsible for over 90 percent of all ammonia emissions; ammonia composes more than 40 percent of the total estimated nitrogen emissions from all sources. Once airborne, these volatile pollutants may be deposited onto nearby streams, rivers, and lakes. Data from Sampson County, North Carolina show that "ammonia rain" has increased as the hog industry has grown, with ammonia levels in rain more than doubling between 1985 and 1995 (Aneja *et al.*, 1998).

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#### ***National Study of Nitrogen Sources to Watersheds***

*In 1994, the USGS analyzed potential nitrogen sources to 107 watersheds, including manure (from both confined and unconfined animals), fertilizers, point sources, and atmospheric deposition. While the study found that proportions of nitrogen originating from various sources differ according to climate, hydrologic conditions, land use, population, and physical geography, results for selected watersheds for the 1987 base year showed that in some instances, nitrogen from manure represents a large portion of the total nitrogen added to the watershed. For example, in nine study watersheds more than 25 percent of nitrogen originates from manure.*

***Source:*** Puckett, 1994.

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Ammonia is highly toxic to aquatic life and is a leading cause of fish kills. In a May 1997 incident in Wabasha County, Minnesota, ammonia in a dairy cattle manure discharge killed 16,500 minnows and white suckers (CWAA, 1998). In addition, ammonia and other pollutants in manure exert a direct biochemical oxygen demand (BOD) on the receiving water. As ammonia is oxidized, dissolved oxygen is consumed. Moderate depressions of dissolved oxygen are associated with reduced species diversity, while more severe depressions can produce fish kills (USFWS, 1991).

#### **2.2.1.2 Phosphorus**

Like nitrogen, phosphorus is necessary for the growth of plants, but is damaging in excess amounts. Phosphorus exists in solid and dissolved phases, in both organic and inorganic forms. Over 70 percent of the phosphorus in animal manure is in the organic form (USDA, 1992). As manure ages, phosphorus mineralizes to inorganic phosphate compounds that are available to plants. Organic phosphorus compounds are generally water soluble and may leach through soil to groundwater or runoff into surface waters. In contrast, inorganic phosphorus tends to adhere to soils and is less likely to leach into groundwater, though it can reach surface waters through erosion or over-application. A report by the Agricultural Research Service noted that phosphorus bound to eroded sediment particles makes up 60 to 90 percent of phosphorus transported in surface runoff from cultivated land (USDA/ARS, 1999). Animal wastes typically have lower nitrogen-to-phosphorus ratios than crop requirements. The application of manure at a nitrogen-based agronomic rate can therefore result in application of phosphorus at several times the agronomic rate. Soil test data in

the United States confirm that many soils in areas dominated by animal-based agriculture exhibit excessive levels of phosphorus (Sims, 1995).

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***Available Nitrogen and Phosphorus  
1998 U.S. Department of Agriculture Study***

*In 1998, the USDA studied the amount of manure nitrogen and phosphorus produced by confined animals relative to crop uptake potential. USDA evaluated the quantity of nutrients available from recoverable livestock manure relative to crop growth requirements, by county, based on data from the 1992 Census of Agriculture. The analyses did not consider manure from grazing animals in pasture. When calculating available nutrients, USDA also corrected for unrecoverable manure, nutrient losses that occur during storage and treatment, and losses to the environment that can occur through runoff, erosion, leaching to groundwater, and volatilization (especially for nitrogen in the form of ammonia). Considering typical management systems, USDA estimates that average manure nitrogen losses range from 31 to 50 percent for poultry, 60 to 70 percent for cattle (including the beef and dairy categories), and 75 percent for swine. The typical phosphorus loss is 15 percent.*

*USDA's study examined the potential for available manure nitrogen and phosphorus generated to meet or exceed plant uptake in each of the 3,141 mainland counties, considering harvested non-legume cropland and hayland. Based on the analysis of 1992 conditions, available manure nitrogen exceeds crop system needs in 266 counties, and available manure phosphorus exceeds crop system needs in 485 counties. The relative excess of phosphorus compared to nitrogen is expected because manure is typically nitrogen-deficient relative to crop needs. Therefore, when manure is applied to meet a crop's nitrogen requirement, phosphorus is typically over-applied with respect to crop requirements (Sims, 1995).*

*These analyses do not evaluate environmental transport of applied manure nutrients. Therefore, an excess of nutrients does not necessarily indicate that a water quality problem exists; likewise, a lack of excess nutrients does not imply the absence of water quality problems. Nevertheless, the analyses provide a general indicator of excess nutrients on a broad basis.*

***Source:*** Lander et al., 1998.

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### **2.2.1.3 Eutrophication**

Eutrophication is a process in which excess phosphorus or nitrogen over-enriches water bodies and disrupts aquatic ecosystems. Excess nutrients cause overgrowth of plants, including fast-growing algae "blooms." Eutrophication can affect the population diversity, abundance, and biomass of phytoplankton and zooplankton, and can increase the mortality rates of aquatic species (USEPA, 1991). Even when algae are not themselves directly harmful to aquatic life, floating algal mats can reduce the penetration of sunlight in the water column and limit growth of seagrass beds and other submerged vegetation. Reduction in submerged aquatic vegetation adversely affects both fish and shellfish populations, and is the leading cause of biological decline in Chesapeake Bay (Carpenter



*et al.*, 1998). The *National Water Quality Inventory: 2000 Report* indicates that excess algal growth alone is among the leading causes of impairment in lakes, ponds, and reservoirs.

Increased algal growth can also raise the pH of water bodies as algae consume dissolved carbon dioxide to support photosynthesis. This elevated pH can harm the gills of aquatic organisms. The pH may then drop rapidly at night, when algal photosynthesis stops. In extreme cases, such pH fluctuations can severely stress aquatic species. In addition, excess nitrogen can contribute to water quality decline by increasing the acidity of surface waters (USEPA, 1995, 1991).

Damage from eutrophication increases when algae blooms die and are digested by bacteria in a decomposition process that depletes the level of oxygen in the water. Dissolved oxygen is necessary for the survival of aquatic life in a healthy ecosystem, and depressed levels of dissolved oxygen can cause widespread morbidity and mortality among aquatic species. Algal decay and night-time respiration can lower the dissolved oxygen content of a water body to levels insufficient to support fish and invertebrates. Severe reductions in dissolved oxygen can result in dramatic fish kills (Carpenter *et al.*, 1998).

In addition to reducing plant diversity and dissolved oxygen, eutrophication can encourage the growth of toxic microorganisms such as cyanobacteria (a toxic algae) and the dinoflagellate *Pfiesteria piscicida*. These organisms can be toxic to both wildlife and humans. Researchers have documented stimulation of *Pfiesteria* growth by swine effluent spills, and have shown that the organism's growth can be highly stimulated by both inorganic and organic nitrogen and phosphorus enrichment (NCSU, 1998).

### **2.2.2 Pathogens**

Pathogens are organisms that cause disease in humans and other species; they include certain species of bacteria, viruses, protozoa, fungi, and algae. Animal waste itself contains hundreds of species of microorganisms, including bacteria, viruses, protozoa, and parasites (USDA, 1998; Jackson *et al.*, 1987; Boyd, 1990). Pathogens may be transmitted directly from manure to surface water, and pathogens already in surface water may increase in number due to loadings of animal manure nutrients and organic matter. Of particular concern are certain pathogens associated with algae blooms. EPA's *National Water Quality Inventory: 2000 Report* focuses on bacterial pathogens and notes that they are the leading stressor in impaired rivers and streams and the fourth-leading stressor in impaired estuaries.

Over 150 pathogens in livestock manure are associated with risks to humans; these include the bacteria *Escheria coli* and *Salmonella* species. and the protozoa *Cryptosporidium parvum* and *Giardia* species. A recent study by the USDA revealed that about half the cattle at the nation's feedlots carry *E. coli* (NAS, 2000). The pathogens *C. parvum*, *Giardia*, and *E. coli* are able to survive and remain infectious in the environment for long periods of time (Stehman, 2000). In

addition, some bacteria in livestock waste cause avian botulism and avian cholera, which have in the past killed tens of thousands of migratory waterfowl annually (USEPA, 1993).

Eutrophication is associated with blooms of a variety of organisms that can be toxic to fish. This includes the dinoflagellate *Pfiesteria piscicida*, which is believed to be the primary cause of many major fish kills and fish disease events in North Carolina estuaries and coastal areas, as well as in Maryland and Virginia tributaries to the Chesapeake Bay (NCSU, 1998; USEPA, 1993). In 1997, hog operations were linked to a *Pfiesteria piscicida* outbreak in North Carolina rivers in which 450,000 fish died (U.S. Senate, 1997). That same year, poultry operation wastes caused *Pfiesteria* outbreaks that killed tens of thousands of fish in Maryland waters, including the Pokomoke River, King's Creek, and Chesapeake Bay (Shields, 1997; Shields and Meyer, 1997; New York Times, 1997).

The generation of toxins associated with eutrophication can also threaten other species. In freshwater, cyanobacterial toxins have caused many incidents of poisoning of wild and domestic animals that have consumed contaminated waters (Health Canada Environmental Health Program, 1998; Carpenter *et al.*, 1998). In coastal waters, visible algae blooms known as red or brown tides have caused significant mortality in marine mammals. Even when algae blooms are not visible, shellfish such as oysters, clams and mussels can carry the toxins from certain algae in their tissue. Shellfish are filter feeders, and pass large volumes of water over their gills to obtain nutrients. As a result, they can concentrate a broad range of microorganisms in their tissues, and provide a pathway for pathogen transmission from surface water to higher trophic organisms (Chai *et al.*, 1994). Information is becoming available to assess the health effects of contaminated shellfish on wildlife receptors. In 1998, the death of over 400 California sea lions was linked to ingestion of mussels contaminated by a bloom of toxic algae (Scholin *et al.*,

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***1995 Algae Blooms and Pfiesteria Outbreaks:  
Neuse River, North Carolina***

*Algae blooms and Pfiesteria outbreaks on the Neuse River in North Carolina during the summer and fall of 1995 were the identified causes of three major fish kills and the suspected causes of several incidents of human illness.*

*Heavy rains in June of 1995 caused overflows of wastewater treatment plants and hog lagoons in the watershed. Within weeks, large mats of algae and aquatic weeds were reported near the town of New Bern on the Trent River, a tributary of the Neuse. By July, historically low levels of dissolved oxygen were recorded in a stretch of the Neuse downstream from New Bern, coinciding with the deaths of over 100,000 fish. A second fish kill in August on another Neuse tributary numbered in the thousands.*

*In September and October a third major fish kill occurred along a 35-mile stretch of the Neuse River itself; the dead fish were covered with sores, and the cause of the outbreak was determined to be the dinoflagellate Pfiesteria. After multiple reports of similar welts and sores on the bodies of those who went swimming or fishing in contaminated areas, state officials declared a health warning, urging people not to swim, boat, or fish in the affected area. In addition, the area was closed to commercial fishing for two weeks.*

***Source:*** Leavenworth, 1995a, 1995b.

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2000). Previous incidents associated the deaths of manatees and whales with toxic and harmful algae blooms (Anderson, 1998).

In August 1997, the National Oceanic and Atmospheric Administration (NOAA) released *The 1995 National Shellfish Register of Classified Growing Waters*. The register characterizes the status of 4,230 shellfish-growing water areas in 21 coastal states, reflecting an assessment of nearly 25 million acres of estuarine and non-estuarine waters. NOAA found that 3,404 shellfish areas had some level of impairment. Of these, 110 (3 percent) were impaired to varying degrees by feedlots, and 280 (8 percent) were impaired by "other agriculture," which could include land where manure is applied (NOAA, 1997).

### **2.2.3 Organic Compounds and Biochemical Oxygen Demand (BOD)**

Livestock manures contain many carbon-based, biodegradable compounds. Once these compounds reach surface water, they are decomposed by aquatic bacteria and other microorganisms. During this process dissolved oxygen is consumed, which in turn reduces the amount of oxygen available for aquatic animals. EPA's *National Water Quality Inventory: 2000 Report* indicates that oxygen-depleting substances are the third leading stressor in estuaries. They are also the fourth leading stressor in impaired rivers and streams and the fifth leading stressor in impaired lakes, ponds, and reservoirs.

Carbon compounds and associated biochemical oxygen demand (BOD) can deplete oxygen and affect the health of aquatic ecosystems in the absence of any other pollutants (e.g., due to decaying vegetation).<sup>9</sup> When carbon compounds enter aquatic ecosystems in conjunction with nutrients (which is generally the case in manure-related pollution), the impacts of BOD are compounded by eutrophication and the presence and growth of pathogens. The result is often a rapid decrease in biodiversity. A study of three Indiana stream systems documents such a reduction in biodiversity due to AFOs (Hoosier Environmental Council, 1997). The study found that waters downstream of animal feedlots (mainly hog and dairy operations) contained fewer fish and a limited number of species of fish in comparison with reference sites. It also found excessive algal growth, altered oxygen content, and increased levels of ammonia, turbidity, pH, and total dissolved solids.

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<sup>9</sup> Biochemical oxygen demand (BOD) is an indirect measure of the concentration of biodegradable substances present in an aqueous solution. Anaerobic lagoon effluent from AFOs typically contains BOD values 10 to 200 times higher than treated domestic sewage. See NCAES, 1982; USDA, 1992; USDA/NRCS, 1992/1996.

#### **2.2.4 Solids and Siltation**

Solids from animal manure include the manure itself and any other elements that have been mixed with it, such as spilled feed, bedding, hair, feathers, and corpses. Smaller solids with less weight remain in the water column as "suspended solids" while heavier solids sink to the bottom of receiving waters in the gradual process of "siltation."

Solids entering surface water can degrade aquatic ecosystems to the point of non-viability. Suspended particles can reduce the depth to which sunlight can penetrate, decreasing photosynthetic activity and the resulting oxygen production by plants and phytoplankton. The increased turbidity also limits the growth of aquatic plants, which serve as critical habitat for fish, crabs, shellfish, and other aquatic organisms upon which these animals feed. In addition, suspended particles can clog fish gills, reduce visibility for sight feeders, and disrupt migration by interfering with a fish's ability to navigate using chemical signals (Goldman and Horne, 1983; Abt, 1993). EPA's *National Water Quality Inventory: 2000 Report* indicates that suspended solids from all sources are the fourth leading stressor in lakes, ponds, and reservoirs.

A major source of siltation is erosion from agricultural lands, including AFOs, cropland, and grazing lands (USEPA, 1992b). Silt can contain heavier manure particles as well as the soil particles carried by erosion. Such sediment can smother fish eggs and otherwise interrupt the reproduction of aquatic species (Boyd, 1990). It can also alter or destroy habitat for benthic organisms. Solids can also degrade drinking water sources, thereby increasing treatment costs.

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#### ***Arkansas Water Quality Inventory Report: Agricultural Activities and Turbidity***

*Arkansas' 1996 Water Quality Inventory Report discussed a sub-watershed in northwestern Arkansas. Land uses in that area, primarily poultry production and pasture management, are major sources of nutrients and chronic high turbidity, and water in the area only partially supports aquatic life.*

***Source: USEPA, 1993.***

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#### **2.2.5 Salts and Trace Elements**

Animal manure contains a number of salts and trace elements such as metals. While these contaminants do not directly alter or interfere with ecosystem processes such as oxygen availability, they are toxic in high concentrations, both to animals and plants. For example, bottom feeding birds may be susceptible to metal toxicity because they are attracted to shallow feedlot wastewater ponds and waters adjacent to feedlots. In addition, metals can remain in aquatic ecosystems for long periods of time because of adsorption to suspended or bed sediments or uptake by aquatic biota.

The salinity of animal manure is due to the presence of dissolved mineral salts. In particular, significant concentrations of soluble salts containing sodium and potassium remain from undigested

feed that passes unabsorbed through animals.<sup>10</sup> Salinity tends to increase as the volume of manure decreases during decomposition, and can have an adverse effect on aquatic life and drinking water supplies (Gresham *et al.*, 1990). Repeated application of manure can lead to increased soil salinity in the root zone and on top of the soil, where it can damage crops; to reduce salinity farmers apply excess water, and salts are washed into surface waters in runoff. In fresh waters, increasing salinity can disrupt the ecosystem, making it difficult for resident species of plants and animals to remain. For example, laboratory experiments have linked increased salinity with inhibited growth and slowed molting in mallard ducklings (USFWS, 1992).

Trace elements in manure can include arsenic, copper, selenium, zinc, cadmium, molybdenum, nickel, lead, iron, manganese, aluminum, and boron. Of these, arsenic, copper, selenium, and zinc are often added to animal feed as growth stimulants or biocides (Sims, 1995). Trace metals may also end up in manure through use of pesticides that are applied to livestock to suppress houseflies and other pests (USDA/ARS, 1998).

A recent Iowa investigation of chemical and microbial contamination near large scale swine operations demonstrated the presence of trace elements not only in manure lagoons used to store swine waste before it is land applied, but also in drainage ditches, agricultural drainage wells, tile line inlets and outlets, and an adjacent river (CDCP, 1998). Similarly, USFWS has reported on suspected impacts from a large number of cattle feedlots on Tierra Blanca Creek, upstream of the Buffalo Lake National Wildlife Refuge in the Texas Panhandle. USFWS found elevated concentrations of the feed additives copper and zinc in the creek sediment (USFWS, 1991).

### **2.2.6 Odorous/Volatile Compounds**

Sources of volatile compounds and odor from AFOs include animal confinement buildings, manure piles, waste lagoons, and land application sites, where decomposition of animal wastes by microorganisms produces gases. The four main gases generated are carbon dioxide, methane, hydrogen sulfide, and ammonia. Aerobic conditions yield mainly carbon dioxide, while anaerobic conditions that dominate in typical, unaerated animal waste lagoons generate both methane and carbon dioxide. Anaerobic conditions are also associated with the generation of hydrogen sulfide and about 40 other odorous compounds, including volatile fatty acids, phenols, mercaptans, aromatics, sulfides, and various esters, carbonyls, and amines (USDA, 1992; Bouzaher *et al*, 1993).

Volatile compounds affect aquatic ecosystems through atmospheric deposition; ammonia (discussed in Section 2.2.1.1) is the most important AFO-related volatile because it is itself toxic and also contributes to eutrophication as a source of nitrogen. Other compounds are less clearly associated with broad ecological impacts, but may have localized impacts.

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<sup>10</sup> See Boyd, 1990 and NCAES, 1982. Other major cations contributing to manure salinity are calcium and magnesium; the major anions are chloride, sulfate, bicarbonate, carbonate, and nitrate. See NRC, 1993.

### 2.2.7 Other Pollutants and Ecosystem Effects

In addition to the pollutants discussed above, pesticides, antibiotics, and hormones used in animal feeding operations may exist in animal wastes and may be present in increased levels in the environment (USDA/ARS, 1998). These compounds may pose risks such as chronic aquatic toxicity (from pesticides) and reproductive impairment (from hormones). While there is limited information on the quantities of these compounds that reach surface waters from AFOs, some research suggests that manure-related runoff may be a significant source of these contaminants.

- **Pesticides:** Pesticides are used to suppress houseflies and other livestock pests. There is little information on the rate at which pesticides in manure enter surface water, but a 1999 literature review by the University of Minnesota notes a 1994 study that links quantities of cyromazine (used to control flies in poultry litter) in runoff to the rate of manure application and rainfall intensity. The review also identifies a 1995 study finding that roughly one percent of all applied pesticides enter surface water. The impacts of these compounds on aquatic ecosystems are unclear, but there is some concern that pesticides may contribute to endocrine disruption (Mulla, 1999).
- **Hormones:** Animal operations use a variety of hormones such as steroids (e.g., estrogen, progesterone, testosterone) and proteins (e.g., prolactin, growth hormone) to improve animal health and productivity. Studies have identified hormones in animal manures. Naturally high hormone concentrations in birds contribute to higher hormone levels in poultry manure, including measurable amounts of estrogen and testosterone. When present in high concentrations, hormones in the environment are linked to reduced fertility, mutations, and the death of fish. There is evidence that fish in some streams are experiencing endocrine disruption (Shore *et al.*, 1995; Mulla, 1999).<sup>11</sup>
- **Antibiotics** The majority of livestock (roughly 60 to 80 percent) receive antibiotics during their productive life span. Some of these agents are used only therapeutically (e.g., to treat illness), but in both the swine and poultry industries, most antibiotics are administered as feed additives to promote growth or to improve feed conversion efficiency. Essentially all of an

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<sup>11</sup> The presence of estrogen and estrogen-like compounds in surface water has been the focus of recent research. While their ultimate fate in the environment is unknown, studies indicate that no common soil or fecal bacteria can metabolize estrogen (Shore *et al.*, 1995). Estradiol, an estrogen hormone, was found in runoff from a field receiving poultry litter at concentrations up to 3.5 micrograms per liter (ug/L). Fish exposed to 0.25 ug/L of estradiol can undergo gender changes, and exposures at levels above 10 ug/L can be fatal (Mulla, 1999).

antibiotic administered is eventually excreted, either unchanged or in metabolite form (Tetra Tech, 2000). Little information is available regarding the concentrations of antibiotics in animal wastes, or on the fate and transport of antibiotics in the environment. However, the key concern related to antibiotics in animal manure is the potential emergence of antibiotic-resistant pathogens in surface and drinking water. As antibiotics use has increased, more strains of antibiotic resistant pathogens are emerging (Mulla, 1999).

Finally, manure pollutants of all types can affect terrestrial as well as aquatic ecosystems. Over-application of manure, in particular, can have terrestrial effects. High oxygen depletion rates due to microbial activity have been reported in manure-amended agricultural soils. In addition, elevated microbial populations can affect crop growth by competing with plant roots for soil oxygen and nutrients. Trace elements (e.g., feed additives such as arsenic, copper, and selenium) and salts in animal manure can accumulate in soil and become toxic to plants (USDA, 1992 and USFWS, 1991).

## **2.3 HUMAN HEALTH IMPACTS RELATED TO AFO POLLUTANTS**

Human health impacts from waterborne manure-related contaminants are primarily associated with drinking contaminated water, contact with contaminated water, and consuming contaminated shellfish. The most common causes of health effects are ingestion of nitrates in drinking water, ingestion of water containing pathogens from manure, and contact with or ingestion of harmful algae or toxic algal by-products. The ingestion of elevated concentrations of trace elements (e.g., arsenic, copper, selenium, and zinc) may also affect human health, and certain gases associated with AFOs may directly and indirectly (i.e., through the formation of secondary particulate matter) pose inhalation risks for nearby residents.

While some recorded human health effects stem from contamination of public drinking water supplies and ingestion of shellfish, more frequently health effects are caused by contamination of private wells, or recreational ingestion or contact. Public water supplies are generally protected by monitoring and treatment, though contaminants and algae blooms may increase treatment costs and affect system operation. Ingestion of contaminated shellfish is reduced by monitoring and closure of shellfish beds in response to excessive levels of contaminants.

### **2.3.1 Health Impacts Associated with Nitrates**

Nitrogen in manure is easily transformed into nitrate form, which can be transported to drinking water sources (e.g., through leaching to groundwater) and presents a range of health risks. EPA found that nitrate is the most widespread agricultural contaminant in drinking water wells, and estimates that 4.5 million people served by wells are exposed to elevated nitrate levels (USEPA,

1990). Elevated nitrate levels can cause nitrate poisoning, particularly in infants (this is known as methemoglobinemia or "blue baby syndrome"), in which potentially fatal oxygen starvation gives a "blue" appearance to the skin. In addition to blue baby syndrome, low blood oxygen due to methemoglobinemia has been linked to birth defects, miscarriages, and poor health in humans and animals.<sup>12</sup>

Reported cases of methemoglobinemia are most often associated with wells that were privately dug and that may have been badly positioned in relation to the disposal of human and animal excreta (Addiscott *et al.*, 1991). Reported cases of methemoglobinemia are rare, though the incidence of actual cases may be greater than the number reported. Studies in South Dakota and Nebraska have indicated that most cases of methemoglobinemia are not reported. Under-reporting may result from the fact that methemoglobinemia can be difficult to detect in infants because its symptoms are similar to other conditions. In addition, doctors are not always required to report it (Michel, 1996; Meyer, 1994).

In 1995, several private wells in North Carolina were found to be contaminated with nitrates at levels 10 times higher than the health standard; this contamination was linked with a nearby hog operation (Warrick 1995c, 1995d). In 1982, nitrate levels greater than 10 milligrams per liter were found in 32 percent of the wells in Sussex County, Delaware; these levels were associated with local poultry operations (Chapman, 1996). In southeastern Delaware and the Eastern Shore of Maryland, where poultry production is prominent, over 20 percent of wells were found to have nitrate levels exceeding EPA's maximum contaminant level (MCL) (Ritter *et al.*, 1989). Nitrate is not removed by conventional drinking water treatment processes. Its removal requires additional, relatively expensive treatment units.

### **2.3.2 Health Impacts Associated with Algal Blooms**

Eutrophication can affect human health by encouraging the formation of algal blooms. Some algae release toxins as they die and may affect human health through dermal contact or through consumption of contaminated water or shellfish. In marine ecosystems, algal blooms such as red tides form toxic byproducts that can affect human health through recreational contact or consumption of contaminated shellfish (Thomann and Muller, 1987). In freshwater, blooms of cyanobacteria (blue-green algae) may pose a serious health hazard to those who consume the water. When cyanobacterial blooms die or are ingested, they release water-soluble compounds that are toxic to the nervous system and liver (Carpenter *et al.*, 1998).

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<sup>12</sup> See USEPA, 1991. In addition, studies in Australia found an increased risk of congenital malformations with consumption of high-nitrate groundwater. Nitrate- and nitrite-containing compounds also have the ability to cause hypotension or circulatory collapse. Nitrate metabolites such as N-nitroso compounds (especially nitrosamines) have been linked to severe human health effects such as gastric cancer. See Bruning-Fann and Kaneene, 1993.



Non-toxic algae blooms triggered by nutrient pollution can also affect drinking water by clogging treatment plant intakes and by producing objectionable tastes and odors. In addition, increased algae in drinking water sources can increase production of harmful chlorinated byproducts (e.g., trihalomethanes) by reacting with chlorine used to disinfect drinking water.

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### ***Impacts of Manure Pollutants on Water Treatment Costs***

*Public water providers may incur considerable expenses associated with removing manure-related contaminants and algae from public water supplies. For example:*

- ▶ *In California's Chino Basin, it could cost over \$1 million per year to remove the nitrates from drinking water due to loadings from local dairies.*
- ▶ *In Wisconsin, the City of Oshkosh has spent an extra \$30,000 per year on copper sulfate to kill the algae in the water it draws from Lake Winnebago. The thick mats of algae in the lake have been attributed to excess nutrients from manure, commercial fertilizers, and soil.*
- ▶ *In Tulsa, Oklahoma, excessive algal growth in Lake Eucha is associated with poultry farming. The city spends \$100,000 per year to address taste and odor problems in the drinking water.*

**Sources:** *For more details on these examples, see USEPA, 1993; Behm, 1989; Lassek, 1998; and Lassek, 1997.*

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### **2.3.3 Health Impacts Associated with Pathogens**

Over 150 pathogens in livestock manure are associated with risks to humans (Juranek, 1991; CAST, 1992). Although human contact can occur through contaminated drinking water, adequate treatment of public water supplies generally prevents exposure. Most exposure occurs through incidental ingestion during recreation in contaminated waters or through ingestion of contaminated shellfish (Stelma and McCabe, 1992). Relatively few microbial agents are responsible for the majority of human disease outbreaks from water-based exposure routes. Intestinal infections are the most common type of waterborne infection, but contact recreation with pathogens can also result in infections of the skin, eye, ear, nose, and throat (Juranek, 1995; and Stehman, 2000). In 1989, ear and skin infections and intestinal illnesses were reported in swimmers as a result of discharges from a dairy operation in Wisconsin (Behm, 1989).

A study for the period 1989 to 1996 revealed that *Cryptosporidium parvum* (a pathogen associated with cows) was one of the leading causes of infectious water-borne disease outbreaks in which an agent was identified. *C. parvum* can produce gastrointestinal illnesses such as cryptosporidiosis, with symptoms that include severe diarrhea (Stehman, 2000). While otherwise healthy people typically recover quickly from illnesses such as cryptosporidiosis, these diseases can be fatal in certain subpopulations, including children, the elderly, people with HIV infection,

chemotherapy patients, and those taking medications that suppress the immune system.<sup>13</sup> In Milwaukee, Wisconsin in 1993, *C. parvum* contamination of a public water supply caused more than 100 deaths and an estimated 403,000 illnesses. The source was not identified, but speculated sources include runoff from cow manure application sites (Casman, 1996). More recently, a May, 2000 outbreak of *Escherichia coli* O157:H7 in Walkerton, Ontario resulted in at least seven deaths and 1,000 cases of intestinal problems; public health officials theorize that flood waters washed manure contaminated with *E. coli* into the town's drinking water well (Brooke, 2000).

Algae blooms are associated with a variety of organisms that are toxic to humans, including the algae associated with "red tide" and a number dinoflagellates. One pathogen of particular concern is the estuarine dinoflagellate *Pfiesteria piscicida*. While *Pfiesteria* is primarily associated with fish kills and fish disease events, the organism has also been linked with human health impacts through dermal or inhalation exposure. Researchers working with dilute toxic cultures of *Pfiesteria* have exhibited symptoms such as skin sores, severe headaches, blurred vision, nausea/vomiting, sustained difficulty breathing, kidney and liver dysfunction, acute short-term memory loss, and severe cognitive impairment. In addition, people with heavy environmental exposure have exhibited symptoms as well. In a 1998 study, such environmental exposure was definitively linked with cognitive impairment, and less consistently linked with physical symptoms (NCSU, 1998; Morris *et al.*, 1998).

While many soil types prevent most pathogens from reaching aquifers, groundwater in areas of sandy soils, limestone formations, or sinkholes is more vulnerable to contamination. Private wells, in particular, are prone to contamination because they tend to be shallower than public wells and therefore more susceptible to contaminants leaching from the surface.<sup>14</sup> While the general extent of groundwater contamination from AFOs is unknown, there are incidents that indicate a connection between livestock waste and contaminated well water. For example, in cow pasture areas of Door County, Wisconsin, where a thin topsoil layer is underlain by fractured limestone bedrock, groundwater wells have commonly been shut down due to high bacteria levels (Behm, 1989).

### **2.3.4 Health Impacts Associated with Trace Elements and Salts**

Trace elements in manure include feed additives such as zinc, arsenic, copper, and selenium. While these are necessary nutrients, they are toxic at elevated concentrations, and tend to persist in

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<sup>13</sup> By the year 2010, about 20 percent of the human population (especially infants, the elderly, and those with compromised immune systems) will be classified as particularly vulnerable to the health effects of pathogens (Mulla, 1999).

<sup>14</sup> In a 1997 survey of drinking water standard violations in six states over a four-year period, the U.S. General Accounting Office reported that bacterial standard violations occurred in up to 6 percent of community water systems each year and in up to 42 percent of private wells. See USGAO, 1997.

the environment and to bioconcentrate in plant and animal tissues. Trace elements are associated with a variety of illnesses. For example, over-exposure to selenium can cause liver dysfunction and loss of hair and nails, while ingestion of too much zinc can produce changes in copper and iron balances, particularly copper deficiency anemia (IRIS, 2000).

Total concentrations of trace elements in animal manures have been reported as comparable to those in some municipal sludges, with typical values well below the maximum concentrations that EPA allows in land-applied sewage sludge (Sims, 1995). Based on this information, trace elements in agronomically applied manures should pose little risk to human health and the environment. However, repeated application of manures above agronomic rates could result in exceedances of the cumulative metal loading rates that EPA considers safe, potentially affecting human health and the environment. There is some evidence that this is happening. For example, in 1995, zinc and copper were found building to potentially harmful levels on the fields of a North Carolina hog farm (Warrick and Stith, 1995b).

Salts in manure can also affect the salinity of drinking water. Increased salts in drinking water can in turn increase blood pressure in salt-sensitive individuals, increasing the risk of stroke and heart attack (Anderson, 1998; Boyd, 1990).

### **2.3.5 Other Health Impacts**

Potential health effects associated with other contaminants in manure include inhalation-related risks associated with volatile organic chemicals and odors, and the effects of hormones, antibiotics, and pesticides that are found in animal feed.

### **Volatile Compounds**

In 1996, the Minnesota Department of Health found levels of hydrogen sulfide gas at residences near AFOs that were high enough to cause symptoms such as headaches, nausea, vomiting, eye irritation, respiratory problems (including shallow breathing and coughing), achy joints, dizziness, fatigue, sore throats, swollen glands, tightness in the chest, irritability, insomnia, and blackouts (Hoosier Environmental Council, 1997). In an Iowa study, neighbors within two miles of a 4,000-sow swine facility reported more physical and mental health symptoms than a control group (Thu, 1998). These symptoms included chronic bronchitis, hyperactive airways, mucus membrane irritation, headache, nausea, tension, anger, fatigue, and confusion. Odor is itself a significant concern because of its documented effect on moods, such as increased tension, depression, and fatigue (Schiffman *et al.*, 1995). Heavy odors are the most common complaint from neighbors of swine operations (Agricultural Animal Waste Task Force, 1996).

## **Pesticides**

Various ingredients in pesticides have been linked to a variety of human health effects, such as systemic toxicity and endocrine disruption (see below). However, information linking pesticide levels in surface and drinking water to human exposure and to animal manure is currently limited. It is therefore unclear what health risks are posed by pesticide concentrations in AFO wastes.

## **Hormones and Endocrine Disruption**

Hormones in the environment can act as endocrine disruptors, altering hormone pathways that regulate reproductive processes in both human and animal populations. Estrogen hormones have been implicated in the drastic reduction in sperm counts among European and North American men (Sharpe and Skakkebaek, 1993) and widespread reproductive disorders in a variety of wildlife (Colburn *et al.*, 1993). A number of agricultural chemicals have also been demonstrated to cause endocrine disruption as well, including pesticides (Shore *et al.*, 1995). The effects of these chemicals on the environment and their impacts on human health through environmental exposures are not completely understood, but they are currently being studied for evidence that they cause neurobiological, developmental, reproductive, and carcinogenic effects (Tetra Tech, 2000). No studies exist on the human health impact of hormones from manure watersheds.

## **Antibiotics and Antibiotic Resistance**

While antibiotics themselves are not generally associated with human health impacts, antibiotic resistance poses a significant health threat. In April 2000, the New England Journal of Medicine published an article that discussed the case of a 12-year old boy infected with a strain of *Salmonella* that was resistant to no fewer than 13 antimicrobial agents (Fey, 2000). The cause of the child's illness is believed to be exposure to the cattle on his family's Nebraska ranch. The Centers for Disease Control, the Food and Drug Administration, and the National Institutes of Health issued a draft action plan in June, 2000, to address the increase in antibiotic resistant diseases (CDCP, 2000). The plan is intended to combat antimicrobial resistance through surveys, prevention and control activities, research, and product development. Some actions are already underway.

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Pollutants associated with AFOs can have a range of harmful impacts on water quality, on aquatic and shoreline ecosystems, and on the range of uses (or services) that water resources provide. While some pollutants pose a direct threat to human health (e.g., pathogens that prevent drinking or contact with contaminated water), AFO-related pollutants can also contribute to the decline of recreational and commercial activities, injury to species that live in or depend on contaminated waters (e.g., aquatic shorebirds), and even a reduction in the intrinsic "existence" value that people place on a pristine or well-protected ecosystem.

The benefits of a regulation that reduces AFO pollution are reflected by identifiable changes in environmental quality that result from the regulation, and by the related improvements in the range of potential uses of the resource. The value of the regulation is then measured according to the value that people place on the changes in these potential uses. EPA characterizes these changes by considering the use and non-use benefits that water resources provide under baseline conditions, and contrasting these benefits with the enhanced benefits realized under each of the regulatory scenarios.

This chapter describes the general approach that EPA uses to value environmental quality improvements associated with reduced AFO pollution. The first section describes the types of environmental improvements and benefits to humans that would likely result from changes in water quality due to the regulation of CAFOs. The chapter then identifies the key environmental changes and benefits that are the focus of the evaluation of EPA's proposed regulations, and describes EPA's approaches to measuring and valuing the selected benefits. The broad methods outlined in this chapter form the basis of the specific benefits analyses described in Chapters 4 through 10.

### **3.1 POSSIBLE ENVIRONMENTAL IMPROVEMENTS AND RESULTING BENEFITS**

Groundwater and surface water resources (including rivers, lakes, estuaries, and oceans) provide a range of benefits to humans and other species that reflect the actual and potential "uses" that they support. Potential uses can include active consumption or diversion of water for industry, agriculture, or drinking water, and can also include a range of active and passive "in-place" uses such as swimming, fishing, and aesthetic enjoyment.

Water resources also provide intrinsic (or non-use) benefits that reflect the importance of protecting environmental quality regardless of any specific use that humans may enjoy or intend. Intrinsic benefits include "existence value," i.e., the sense of well-being that people derive from the existence of pristine water resources, even when they do not expect to see or use these resources.<sup>1</sup> The protection of resources for future generations (intergenerational equity) or for non-human species (ecological benefits) are other key intrinsic benefits.

Degradation of a water resource may restrict its use or the intrinsic benefits it provides, and therefore reduce its value. Conversely, improvement in environmental quality provides benefits associated with an increase in the range of potential uses and intrinsic benefits that a resource can support. Exhibit 3-1 provides a summary of the potential benefits associated with an improvement in the quality of aquatic resources.

<b>Exhibit 3-1</b>	
<b>POTENTIAL BENEFITS OF WATER QUALITY IMPROVEMENTS</b>	
<b>Use Benefits</b>	
In-Stream	<ul style="list-style-type: none"> <li>• Commercial fisheries, shell fisheries, and aquaculture; navigation</li> <li>• Recreation (fishing, boating, swimming, etc.)</li> <li>• Subsistence fishing</li> <li>• Human health risk reductions</li> </ul>
Near Stream	<ul style="list-style-type: none"> <li>• Water-enhanced non-contact recreation (picnicking, photography, jogging, camping, etc.)</li> <li>• Nonconsumptive use (e.g., wildlife observation)</li> </ul>
Option Value	<ul style="list-style-type: none"> <li>• Premium for uncertain future demand</li> <li>• Premium for uncertain future supply</li> </ul>
Diversionary	<ul style="list-style-type: none"> <li>• Industry/commercial (process and cooling waters)</li> <li>• Agriculture/irrigation</li> <li>• Municipal/private drinking water (treatment cost savings and/or human health risk reductions)</li> </ul>
Aesthetic	<ul style="list-style-type: none"> <li>• Residing, working, traveling and/or owning property near water, etc.</li> </ul>
<b>Intrinsic (Non-Use) Benefits</b>	
Bequest	<ul style="list-style-type: none"> <li>• Intergenerational equity</li> </ul>
Existence	<ul style="list-style-type: none"> <li>• Stewardship/preservation</li> <li>• Vicarious consumption</li> </ul>
Ecological	<ul style="list-style-type: none"> <li>• Reduced mortality/morbidity for aquatic and other species</li> <li>• Improved reproductive success for aquatic and other species</li> <li>• Increased diversity of aquatic and other species</li> <li>• Improved habitat, etc.</li> </ul>

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<sup>1</sup> A common example of intrinsic value is the broad public support for the preservation of National Parks, even by people who do not expect to visit them.

AFO pollutants have impacts on a broad range of water resource services. Pollution by nutrients, for example, can reduce the value of both groundwater and surface water as a drinking water source, and algae in eutrophied surface water can reduce recreational and aesthetic uses (due to foul odor and appearance), as well as clog municipal and industrial intakes. Acute nitrogen loadings and decaying algae cause fish kills, which affect commercial and recreational fishing, and indicate injury to natural resources; some of these injuries may require restoration in order to achieve full recovery of the ecosystem. Both chronic and acute nutrient loadings can reduce aquatic populations and the shoreline species that depend on them; this affects both opportunities to view wildlife and ecological "existence" values. Finally, nutrient-related red tide and *Pfiesteria* events can restrict access to shellfish and beaches, affecting shellfishing and recreational opportunities.

Other AFO pollutants have similar impacts or can cause additional effects (e.g., turbidity from solids, human health effects from pathogens). In addition, any pollutant that reduces the quality of an environmental resource may adversely affect intrinsic values, such as bequest values (i.e., preserving environmental quality for future generations). While the beneficial impacts of improved control of any one pollutant can be difficult to isolate, AFO-related pollution generally involves a broad range of impacts that, taken together, affect to some degree most of the potential uses and intrinsic benefits of water resources.

### 3.2 SPECIFIC BENEFITS ANALYZED

The benefits of water quality improvements are a function of the specific pollutants reduced, the water resources affected, and the improvements in the potential uses of these resources. The key challenge of a benefits calculation is to establish a clear link between the implementation of a regulation, the reduction of a pollutant, the resulting improvement in environmental quality, and the value of that improvement.

While AFO-related pollutants can affect most potential uses of surface and groundwater, EPA has identified a set of environmental quality changes that meet three criteria: 1) they represent identifiable and measurable changes in water quality; 2) they can be linked with the proposed CAFO regulations; and 3) together, they represent a broad range of potential human uses and benefits and are likely to capture important environmental changes that result from the rule. Specifically, EPA implements the following analyses:

- **Improvements in Water Quality and Suitability for Recreational Activities:** this analysis addresses increased opportunities for recreational boating, fishing, and swimming, as well as the potential increase in non-use values associated with improvements in inland surface water quality;
- **Reduced Incidence of Fish Kills:** this analysis assesses the value of reducing the incidence of fish kills attributable to pollution from AFOs;

- **Improved Commercial Shell Fishing:** this analysis characterizes the impact of pollution from AFOs on access to commercial shellfish growing waters, and values the potential increase in commercial shellfish harvests that may result from improved control of that pollution;
- **Reduced Contamination of Private Wells:** this analysis values the impact of the revised regulations in reducing the concentration of nitrates in water drawn from private wells;
- **Reduced Contamination of Animal Water Supplies:** this analysis characterizes the effect of pollution from AFOs on livestock mortality, and values the potential impact of the revised regulations in reducing mortality rates;
- **Reduced Eutrophication of Estuaries:** this analysis examines the impact of the revised regulations on nutrient loadings to selected estuaries, and presents a case study illustrating the potential economic benefits of the anticipated reduction in such loads; and
- **Reduced Water Treatment Costs:** this analysis examines the revised regulations' beneficial effect on source water quality and the consequent reduction in treatment costs for public water supply systems.

EPA's analysis does not attempt to comprehensively identify and value all potential environmental changes associated with proposed revisions to the CAFO regulations. For example, the analysis of the suitability of water resources for recreational use excludes most estuarine or marine waters. In addition, the analysis does not value the potential impact of improvements in water quality on near-stream activities, such as birdwatching or camping, nor does it consider non-water related benefits, such as potential reductions in odor from waste management areas.

While changes in water quality resulting from CAFO regulations may have real impacts on these types of uses, and may even be associated with significant benefits, several factors make it difficult to measure the specific impacts of the regulation and identify related changes in value. For example, analysis of potential changes in estuarine or marine water quality nationwide is currently beyond the capabilities of the water quality model employed in this study. In addition, while EPA's proposed CAFO regulations will contribute to improvements in environmental quality beyond surface waters, it is difficult to establish clear relationships between regulation of CAFOs and certain environmental quality changes, such as reductions in odor or improvements in the health of shorebirds. Although these benefits are not specifically addressed by the analysis, they likely represent additional benefits of the regulation.

### 3.3 PREDICTING CHANGE IN ENVIRONMENTAL QUALITY AND RESULTING BENEFICIAL USE

To calculate the benefits associated with new regulations, an analysis must explore the difference between present conditions (i.e., the baseline scenario) and the likely future conditions that would result from the regulation. The baseline scenario is typically assessed using the best and most recently collected data that characterize existing environmental quality. Because likely future conditions are theoretical, the characterization of environmental quality under the new regulations must be evaluated through environmental modeling or other approaches designed to simulate possible future conditions. The anticipated difference in environmental quality under present and future conditions thus represents the marginal environmental quality gains or human benefits that the new regulations are expected to produce.

EPA's analysis of the new CAFO regulations examines the difference between the baseline and expected future conditions once the new regulations have taken effect. Ideally, the baseline scenarios would be constant across benefit categories and analyses; however, data limitations forced EPA to define baseline conditions based on the most up to date record of existing conditions for each analysis. For instance, the analysis of increased commercial shellfish supply benefits relies upon 1995 data on shellfish bed closures to define baseline conditions, whereas the analysis of fish kill events relies upon data collected between 1980 and 1999. Detailed information on the time frame used to define baseline scenarios for each of the selected environmental benefit categories is provided for each of the analyses addressed in Chapters 4 through 10.

For each of the benefit categories analyzed, conditions following implementation of the new regulations are assessed using modeling approaches most applicable to the specific analysis. For each of the selected benefit categories, EPA models anticipated future conditions as follows:

- **Improvements in Water Quality and Suitability for Recreational Activities:** EPA relies on a national water quality model to predict changes in the ambient concentration of pollutants attributable to changes in pollutant loadings from CAFOs. Under each regulatory scenario, the model determines whether estimated changes in pollutant concentrations would improve the suitability of water resources for recreational uses such as boating, fishing, and swimming.
- **Reduced Incidence of Fish Kills:** Through modeling of nitrogen and phosphorus loading reductions, the analysis estimates changes in the frequency of fish kill events under each regulatory scenario.
- **Improved Commercial Shell Fishing:** EPA employs data on the impact of agricultural pollution on commercial shellfish harvesting, combined with modeled estimates of the change in pathogen loadings from CAFOs, to estimate the potential increase in annual shellfish harvests under each regulatory scenario.



- **Reduced Contamination of Private Wells:** EPA employs data from the U.S. Geological Survey (USGS), EPA, and the Bureau of Census to model the relationship between nitrate concentrations in private domestic wells and sources of nitrogen to aquifers. EPA uses this model, combined with estimates of the change in nitrogen loadings following implementation of the new regulations, to predict changes in well nitrate concentrations nationally.
- **Reduced Contamination of Animal Water Supplies:** EPA employs data on livestock mortality at CAFOs, combined with modeled reductions in the loadings of nitrates and pathogens to animal water supplies, to estimate reductions in livestock mortality attributable to the consumption of contaminated water.
- **Reduced Eutrophication of Estuaries:** EPA relies on its national water quality model to estimate the impact of the final rule on loadings of nutrients to 10 estuaries.
- **Reduced Water Treatment Costs:** EPA employs its national water quality model to estimate the impact of the final rule on the concentration of suspended solids in the source waters serving public water supply systems.

### 3.4 VALUING BENEFITS

The final step of the benefits analyses is to estimate the economic value of the modeled physical changes in environmental quality. This section provides a brief overview of economic valuation concepts and discusses the valuation approach applied in the studies performed for the CAFO rule.

#### 3.4.1 Overview of Economic Valuation

Economists define benefits by focusing on measures of individual satisfaction or well-being, referred to as measures of welfare or utility. A fundamental assumption in economic theory is that individuals can maintain the same level of utility while trading-off different "bundles" of goods, services, and money. The tradeoffs individuals make reveal information about the value they place on these goods and services.

The willingness to trade-off compensation for goods or services can be measured by an individuals' willingness to pay. While these measures can be expressed in terms of goods, services, or money, economists generally express willingness to pay in monetary terms. In the case of an environmental policy, willingness to pay represents the amount of money an individual would give up to receive an improvement (or avoid a decrement) in environmental quality.<sup>2</sup>

The use of willingness to pay to measure benefits is closely related to the concept of consumer surplus. Resource economists generally rely on consumer surplus as a measure of overall economic welfare for benefits to individuals. The concept of consumer surplus is based on the principle that some consumers benefit at current prices because they are able to purchase goods (or services) at a price that is less than their total willingness to pay for the good. For example, if a consumer is willing to pay \$4 for an additional gallon of clean drinking water that costs the consumer only \$1.50, then the marginal consumer surplus is \$2.50.

### **3.4.2 Primary Approaches for Measuring Benefits**

Economists generally define the economic benefits provided by a natural resource as the sum of individuals' willingness to pay for the goods and services the resource provides, net of any costs associated with enjoying these services.<sup>3</sup> In some cases (e.g., commercial fishing), natural resource products are traded in the marketplace, and willingness to pay information can be directly obtained from demand for these commodities. In other cases, when natural resource goods or services are not traded in the market, economists use a variety of analytic techniques to value them, or to estimate the economic benefits of improvements in environmental quality.<sup>4</sup> These non-market methods, which are grounded in the theory of consumer choice, utility maximization, and welfare economics, attempt to determine individuals' willingness to pay for natural resource services directly, through survey research, or indirectly, through the examination of behavior in related markets. Descriptions of market and non-market methods for analyzing benefits follow below.

- **Market Methods:** To measure the economic value of environmental improvements, market methods rely upon the direct link between the quality or stock of an environmental good or service and the supply or demand for

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<sup>2</sup> Economists also sometimes consider a similar concept of "willingness to accept compensation"; i.e., the amount of monetary compensation that would make the individual indifferent between having an environmental improvement and foregoing the improvement.

<sup>3</sup> In the case of goods and services traded in the marketplace, net benefits also include producer surplus: the excess of producer revenues over costs. For simplicity, we leave aside for now any discussion of producer surplus in assessing the benefits associated with enjoyment of natural resource services.

<sup>4</sup> These same techniques can be applied to estimate the economic damages attributable to a decline in environmental quality.

that market commodity. Market methods can be used, for example, to characterize the effect of an increase in commercial fish and shellfish harvests on market prices. In turn, these market changes affect the welfare of consumers and producers in quantifiable ways.

- **Revealed Preference:** Revealed preference approaches are premised on the assumption that the value of natural resource services to users of those services can be inferred by indirect economic measures. For example, willingness to pay for recreational beach services can be estimated by observing how the number of visits individuals make to a beach varies with the cost of traveling to the beach. Similarly, property values can be influenced by proximity to an environmental amenity or disamenity; econometric analysis can estimate the nature and magnitude of such effects, providing a basis for valuing natural resource services.
- **Stated Preference:** Stated preference models involve the direct elicitation of economic values from individuals through the use of carefully designed and administered surveys. Contingent valuation techniques are the most widely used stated preference approach, and rely on surveys designed to derive people's willingness to pay for an amenity (e.g., improved water quality) described in the study. This method can be used to estimate both use and non-use values.
- **Averted Cost:** Changes in environmental quality can impose additional costs on the users of an affected resource. For example, contamination of drinking water supplies might lead homeowners to purchase in-home water filters. A potential proxy measure of the benefits of preventing pollution of the resource is the averted cost of these expenditures.

### **3.4.3 Valuation of CAFO Regulatory Benefits Based on Previous Studies**

Because of their high resource demands, the use of primary approaches is beyond the scope of this analysis. Instead, the analysis draws on previous studies that evaluated similar water quality benefits issues. This approach—typically referred to as "benefits transfer"—involves the application of values, functions, or data from existing studies to estimate the benefits of the resource changes currently being considered, and is commonly used in analyzing the benefits of new environmental regulations. The primary research material and analytic approach used for the valuation of each benefit category are summarized below; more detailed descriptions of the methods applied are provided in subsequent chapters of this report.

- **Improvements in Water Quality and Suitability for Recreational Activities:** To determine how people value improvements in the suitability of water resources for recreational activities (e.g., boating, fishing, swimming), the analysis relies on the results of a contingent valuation survey conducted by Carson and Mitchell (1993). Based on this study, the analysis estimates the economic benefits attributable to projected reductions in pollution of the nation's rivers and streams.
- **Reduced Incidence of Fish Kills:** The valuation of benefits from the reduced incidence of fish kills employs two approaches – an estimate based solely on fish replacement costs, as reflected in an American Fisheries Society (1990) report, and an estimate that takes into account potential recreational use values.
- **Improved Commercial Shell Fishing:** To value the economic benefit of increased shellfish harvests, the analysis relies on available literature that models consumers' demand for shellfish. Based on the demand equations from these primary sources, EPA determines the increase in consumer surplus that would result from increased harvests.
- **Reduced Contamination of Private Wells:** The analysis surveys the literature concerning the values people place on avoiding or reducing nitrate contamination in private domestic wells. Based on this review, it develops estimates of people's willingness-to-pay to reduce nitrate concentrations to certain levels, and applies these estimates to value predicted changes in the quality of water that supplies private wells.
- **Reduced Contamination of Animal Water Supplies:** To value reductions in livestock mortality, EPA employs estimates of livestock replacement costs.
- **Reduced Eutrophication of Estuaries:** To characterize the benefits of reduced eutrophication of estuaries, EPA conducts a case study of North Carolina's Albemarle and Pamlico Sounds. The case study estimates the economic benefits of changes in nutrient loadings in this region based on revealed preference studies of the relationship between water quality and willingness to pay for recreational fishing opportunities.
- **Reduced Water Treatment Costs:** EPA relies on estimates of averted drinking water treatment costs to value predicted improvements in source water quality.

#### **3.4.4 Aggregating Benefits**

The final step in determining the benefits of the revised CAFO regulations is aggregation of the benefits calculated for each of the benefit categories. To avoid over-estimation, this requires consideration of the extent to which underlying analyses may double-count certain benefits. For this analysis, however, the benefits that each of the underlying studies explore are relatively distinct. As a result, the potential for double-counting appears to be small.

Another consideration in aggregating benefits is ensuring that all values are reported on a comparable basis, taking into account the effects of inflation on real dollar values. For purposes of this analysis, all values are reported in 2001 dollars. The price indices employed in converting source data to 2001 dollars vary, depending on which index is most appropriate. Further information on these adjustments is provided in the detailed discussion of each analysis.

The detailed analyses presented in Chapters 4 through 10 report benefits on an annual basis. To determine the present value of these benefits, EPA employs three alternative discount rates: a 7 percent real discount rate, which is representative of the real rate of return on private investments and consistent with the rate mandated by the Office of Management and Budget for analysis of proposed regulations; a 3 percent real discount rate, which is representative of the social rate of time preference for consumption of goods and services, and consistent with the rate recommended by many economists for analysis of environmental benefits; and a 5 percent real discount rate, which represents the mid-point of the 3 to 7 percent range.

In calculating the present value of benefits at the time new regulations are implemented, EPA assumes an infinite time frame; i.e., as long as the regulations remain in effect, the associated benefits will be enjoyed in perpetuity. EPA further assumes that its estimates of beneficial impacts on most water resources will be fully realized in the year immediately following implementation of the revised regulations. This assumption reflects EPA's judgment that reductions in the loadings of pollutants from CAFOs will quickly yield improvements in water quality. With respect to reduced contamination of private wells, however, EPA assumes that several years will pass before the full benefits of the regulation are realized. To permit consistent comparison of these benefits to the annual benefits estimated for other water resources, EPA presents the benefits of reduced contamination of private wells on an annualized basis, as well as on a present value basis. The calculation of an annualized value for this benefits category indicates the constant flow of benefits over time that would generate the same present value as the anticipated, uneven, flow of benefits.

Additional information on the calculation of present values and the aggregation of benefits is presented in Chapter 11.

### **3.5 SUMMARY**

Exhibit 3-2 summarizes EPA's approach to measuring and valuing the anticipated benefits of the revised CAFO regulations. Additional information on the methods employed is provided in the detailed discussion of each analysis that follows.

### **3.6 REFERENCES**

AFS. 1990. American Fisheries Society Socioeconomics Section, *A Handbook of Monetary Values of Fishes and Fish-Kill Counting Guidelines*, Draft, July 1990.

Carson, Richard T. and Robert Cameron Mitchell. 1993. "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Water Quality." *Water Resources Research*, Vol. 29, No. 7.

**Exhibit 3-2**

**SUMMARY OF APPROACH TO ESTIMATING REGULATORY BENEFITS**

<b>Benefit Category</b>	<b>Human Use</b>	<b>Measurement Approach</b>	<b>Valuation Approach</b>
Improvements in Water Quality and Suitability for Recreational Activities	Recreational boating, fishing, swimming, and non-use benefits associated with freshwater resources.	Model potential changes in water quality based on estimated changes in loadings of CAFO-related pollutants.	Stated preference approach assessing willingness-to-pay for water quality that supports recreation.
Reduced Incidence of Fish Kills	Recreational fishing, near-stream use and non-use benefits.	Estimate changes in the frequency of fish kill events based on estimated reductions in nutrient loadings.	Avoided damages based on fish replacement costs and estimates of recreational use value.
Improved Commercial Shell Fishing	Commercial shell fishing.	Estimate increased access to shellfish growing waters and resulting increase in annual shellfish harvests, based on modeled changes in fecal coliform concentrations.	Market estimate of increased consumer surplus.
Reduced Contamination of Private Wells	Drinking water.	Model potential changes in private domestic well water quality based on estimated changes in loadings of CAFO-related pollutants.	Stated preference approach assessing willingness-to-pay to reduce the concentration of nitrates in water drawn from private domestic wells.
Reduced Contamination of Animal Water Supplies	Livestock production	Model potential reductions in animal mortality based on estimated changes in exposure to CAFO-related pollutants.	Averted costs of cattle replacement.
Reduced Eutrophication of Estuaries	Recreational fishing	Case study of estimated changes in nutrient loadings to North Carolina's Albemarle and Pamlico Sounds.	Revealed preference-based estimate of relationship between water quality and willingness to pay for recreational fishing opportunities in the region.
Reduced Water Treatment Costs	Drinking water	Estimate reductions in the concentration of total suspended solids in surface waters that supply community drinking water systems.	Averted costs of drinking water treatment.